Bingham Canyon Storm Water Management

Kennecott

Utah Copper Division Mine

BINGHAM CANYON STORM WATER MANAGEMENT
KENNECOTT
UTAH COPPER DIVISION MINE

TREATMENT, CONTROL AND IMPOUNDMENT OF EXCESS STORM WATER DURING THE JULY 1, 1983 - JUNE 30, 1984 RECORD PRECIPITATION YEAR

PREPARED BY
UTAH COPPER DIVISION
ENVIRONMENTAL ENGINEERING DEPARTMENT

AUGUST 1984

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Summary

Until the spring of 1984, Kennecott was able through use of impoundment and evaporation ponds to avoid discharging effluent from its Bingham Mine into water of the United States and thus required no National Pollution Discharge Elimination System (NPDES) permit for the Bingham Mine under the Federal Clean Water Act. When there was evidence in 1982 and 1983 that precipitation in the area might increase beyond previously predicted levels, Kennecott took action to increase its pond capacity at the Bingham Mine substantially so as to avoid effluent discharges. In the winter of 1983-1984, however, there were indications that precipitation might even exceed prior records and Kennecott took action to apply for an NPDES permit against the possibility that effluent discharges from the Bingham Mine might be necessary. Kennecott requested emergency action on the permit.

In fact, record precipitation during 1983 and 1984 resulted in over 5,000 acre-feet of excess water from the Bingham Canyon watershed during the spring snow melt and subsequent runoff. Kennecott implemented an emergency program during the winter and spring to treat, contain and control the excess water at a cost exceeding $5 million. Except for 480 acre-feet of treated water which was pumped to the Jordan River, the total volume of excess water was contained on Kennecott property with no identifiable adverse impact on the environment.

Under EPA's regulations, any NPDES permit issued for the Bingham Mine would have been required to provide that Kennecott was free to discharge any excess water associated with precipitation provided the pond capacity at the Bingham Mine was sufficient to contain all process water and the precipitation, including snowmelt, associated with the largest 24-hour storm event in a 10-year period. In fact, the pond capacity at the Bingham Mine is much greater than the required amount and the 480 acre-feet of treated water discharged to the Jordan River would have qualified under the 10-year, 24-hour storm water exemption. The required holding capacity for ponds capable of accommodating all process water and the maximum 10-year, 24-hour storm event in the area surrounding the Bingham Canyon Mine is 1,034 acre-feet, compared to an actual holding capacity of 3,544 acre-feet.

Based on climatological data and a forecast of potential record occurrence, large-scale construction of containment and evaporation ponds was initiated during the summer of 1983 and continued on an emergency priority basis throughout the winter and spring. Treatment of excess water and diversion to the evaporation ponds commenced in October 1983. Clay lining of additional existing evaporation ponds, additional treatment facilities and facilities to divert excess treated water to the Jordan River were initiated in January 1984 following an evaluation of the snowpack on the Bingham Canyon watershed. A status report was presented to the State of Utah Bureau of Water Pollution and to EPA Region 8 following this evaluation and an application made for an NPDES permit. An approved NPDES Permit No. UT-0024350 was issued by EPA on July 19, 1984.

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Kennecott recognized the climatic change could continue in 1983 and initiated an extensive engineering study of the Bingham Canyon hydrology. The objective of the study is to determine permanent economic and technically feasible solutions to water management problems associated with record runoff and potentially avoid the need for the type of emergency action associated with water control during the past three years.

Even though part of this study is complete, implementation of permanent controls will take several years. Since there is no evidence to indicate the much higher than normal precipitation will not continue for one or even several years, emergency action similar to that implemented in 1983-84 will have to be implemented in 1984-85. Emergency planning for this control is in process and will be implemented as soon as possible to accommodate construction before the adverse winter period.

Listed below is a summary of the emergency water control action taken during the past three years.

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Maximum volume of water from a 10-year, 24-hour precipitation event using a 0.3 runoff coefficient:

$$\frac{2.58^{1} \text{ in.} \times (25.6 \text{ sq. mi.} - 4.6 \text{ sq. mi.})^{2} \times 640 \text{ acres/mi.} \times 0.3}{12 \text{ in./ft.}} = 867 \text{ acre-feet}$$

Total needed capacity = 1,034 acre-feet

Capacity of Bingham Canyon drainage facilities:

Large Bingham Creek Reservoir	= 1,500 acre-feet
Small Bingham Creek Reservoir	= 61 acre-feet
Clay-lined evaporation ponds - 182 acres x 7 feet	= 1,274 acre-feet
Old sludge-lined evaporation ponds[3] - 87 acres x 7 feet + 20 acres x 5 feet	= 709 acre-feet
Total actual capacity	= 3,544 acre-feet

[1]Based on the maximum measured 24-hour precipitation on September 26, 1982 measured in the Bingham Canyon during the past ten years. The measured value is an average of six measuring locations in the watershed area.

[2]The total surface area of the Bingham Canyon watershed is 25.6 square miles. Drainage from 4.6 square miles of this area runs into the mine pit where it is contained. Therefore, the net surface area contributing runoff to the Bingham Canyon is 21 square miles.

[3]This does not include approximately 1,900 acre-feet capacity of unlined evaporation ponds. These ponds have little or no deposition of treatment sludge and, therefore, cannot be considered to be effective containment facilities for the purpose of this calculation.

Mining Activity and Geology

The Kennecott Utah Copper Division Bingham Canyon Mine is located in Bingham Canyon on the west side of the Salt Lake Valley. The mining operation consists of open-pit mining of low-grade copper ore, removal of overburden or waste material and dump leaching of the waste material. It was the first open-pit mining operation in the copper industry and presently the largest open-pit mine in the world. Activity associated with the discovery and subsequent development of the mine began in 1863. Mining of the ore body was limited to underground mining techniques until 1906 when open-pit mining was initiated. Over 4,000,000,000 tons of material have been removed since the mining operation commenced.

The mineral deposit is a porphyry copper ore body containing recoverable amounts of copper, molybdenum, selenium, gold, silver and palladium. Most of the metals occur as sulfide minerals which are extracted by a froth flotation process in the copper concentrating operation. The ore body also contains iron sulfides and trace amounts of several other metal sulfides which are not extracted in the concentrating operation.

The classification of bulk material as waste or ore is an economic determination based on the recoverable metal content of the material and existing market conditions. Generally, the ratio of waste to ore in the mined material is about 2:1. The ore is transported to the concentrators for processing and the waste is transported to overburden dumps in the vicinity of the mine.

The overburden dumps are leached to recover soluble copper. The dissolved copper in the leach water is precipitated using scrap iron as the reagent. The leach system is a zero discharge recirculating system with state of the art collection facilities at the base of the overburden dumps. The recirculation rate is 30,000 to 35,000 GPM with the Bingham Creek Reservoir providing surge capacity either to hold normal excess storm water or provide makeup water. The total volume of water in circulation at any given time is about 1,500 acre-feet. The uncertainty in this estimated volume is the variable resonance time of the recirculated water in the various overburden dumps. About eleven percent of the copper produced from the Bingham Canyon Mine comes from the leaching operation.

Bingham Canyon Watershed and Historical Water Management

Bingham Canyon is located on the east slope of the Oquirrh Mountains. The watershed covers a 25.6 square mile area ranging in elevation from 5300' to 9200'. Historically, drainage from the watershed due to rainfall and spring snowmelt flowed from the canyon east through the Salt Lake Valley into the Jordan River which terminates in the Great Salt Lake (Figure 1). Depending on climatic conditions, the annual precipitation on the Bingham Canyon watershed area averages 24.6 inches with a measured accumulated snowpack averaging 50 inches. Most of the surface runoff from the watershed is due to melting of the accumulated snowpack in the spring.

At the present time, 12.2 square miles of the watershed are covered by mining operations and 13.4 square miles are undisturbed mountain area. Due to the nature of historical mining development, all surface runoff from undisturbed areas except for the actual mine pit area flows through disturbed areas mixing with recirculated leach water and is collected by the leach water collection system (Figure 2).

Surface runoff water which comes in contact with the disturbed ore body becomes acidic and mineralized due to the natural oxidation and dissolution of minerals contained in the ore body. Recognizing the potential to extract dissolved copper from this water, nonrecycle copper precipitation is believed to have been started before 1900. As the surface area of mine waste dumps increased, recycle of water to the dumps was initiated and full-scale copper precipitation operations had become a substantial means of copper production by 1923.

Historically, excess water from copper precipitation operations as well as direct runoff flowed in Bingham Creek to the Jordan River.[1] Evidence shows the mineralized water was occasionally diverted out of Bingham Creek onto open areas to prevent contamination of irrigation canals from the Jordan River which intercept Bingham Creek.

[1] Kennecott, in cooperation with the Utah Division of Environmental Health and Salt Lake County, initiated an extensive five-year groundwater study in 1983 to determine the impact of historical and present mining activity on groundwater between the Bingham Canyon and the Jordan River.

In the 1930's, evaporation ponds were constructed five miles west of Bingham Canyon to contain the mineralized water flowing out of the canyon. These ponds were constructed on a level area which was a historic river delta created by Bingham Creek when Lake Bonneville existed. Because the river delta is a deposit of composite materials overlaying sedimentary clay material on the valley floor, use of the evaporation ponds resulted in seepage from the ponds surfacing at the face of the delta.

In 1965, the Bingham Creek Reservoir was constructed to contain all surface runoff from the Bingham Canyon watershed and provide adequate surge capacity for the leach water recirculation system as well as a source of makeup water for the leaching operation. The 1,500 acre-feet capacity of the reservoir has been sufficient to contain storm water runoff from the Bingham Canyon watershed except for a small amount of excess water during 1973, 1974 and 1975 which was diverted around the reservoir to the evaporation ponds to prevent an uncontrolled overflow of the reservoir.

The reservoir water level increased again during the winter of 1981-82 due to heavy precipitation (Figure 3). To avoid reservoir overflow when the spring runoff occurred, facilities were constructed to route nonmineralized water being pumped from the mine pit and water from the north ore shaft around the reservoir to the evaporation ponds. This diversion, along with increased recirculation to the west side leach dumps during peak runoff, was sufficient to avoid having to discharge excess mineralized water to the evaporation ponds.

Record precipitation during September 1982 and heavy snowfall during the winter of 1982-83 increased the reservoir water level to a point that it was evident the spring runoff would exceed the reservoir capacity (Figure 4). In an attempt to avoid the discharge of leach water to the evaporation ponds, emergency lime treatment facilities were installed to treat excess leach water in March 1983. Between April 20, 1983 and July 17, 1983, 960 acre-feet of leach water were treated, but the amount treated and discharged to the evaporation ponds was insufficient to accommodate the necessary capacity in the reservoir to contain the spring runoff. As a result, 695 acre-feet of untreated water were diverted around the reservoir to the evaporation ponds. The total volume of excess storm water for the 1982-83 water year was 1,655 acre-feet.

The diversion of untreated water around the reservoir was initiated prior to the peak runoff when it became evident the reservoir capacity would be exceeded. Allowing the reservoir to fill to overflow would result in uncontrolled discharge from the spillway which could exceed the structure which diverts the discharge out of the Bingham drainage into a canal going to the evaporation ponds. Overflowing this diversion structure would result in mineralized water flowing down the Bingham drainage which no longer exists as an actual drainage due to residential development in the drainage.

<u>Storm Water Management (July 1, 1983 to June 30, 1984)</u>

As the result of diverting a record amount of excess mine water into the evaporation ponds during the spring of 1983 combined with excessive precipitation during the summer of 1983, substantial seepage occurred at the base of the river delta below the evaporation ponds. The initial seepage accumulated in an abandoned gravel pit on the south side of the delta. During a heavy rainstorm in August 1983 (Figure 5), the seepage exceeded the capacity of the gravel pit and flowed off Kennecott property into the Provo Reservoir Water Users Association Canal.

On an emergency basis, a barrier trench and two small holding ponds were constructed to intercept and contain the seepage flowing into the canal. This discharge was stopped within 24 hours and reported to the appropriate environmental authorities.

Continued diversion of excess mine water into the evaporation ponds and heavy precipitation in September 1983 resulted in additional seepage from the east side of the delta and a substantial increase in the seepage from the south side. On an emergency basis, 79 acres of evaporation ponds having 556 acre-feet capacity were constructed on the south side of the river delta in the underlying clay layer to contain the seepage. Barrier trenches and a holding pond were constructed to collect the seepage from the east side. Pumping facilities and a pipeline were installed to route the water collected on the east side into the new evaporation ponds constructed on the south side (Figure 6). Except for riprap on the largest evaporation pond and land reclamation, the construction of these facilities was completed by December 31, 1983 with all seepage being contained on Kennecott property.

In anticipation of another year of record spring runoff in 1984, treatment of excess mine water was initiated in October 1983 to generate capacity in the reservoir for the spring runoff. The anticipated precipitation materialized when record snowfall occurred during November and December 1983. A survey of the accumulated snowpack and existing remaining reservoir capacity in January 1984 showed the spring runoff would exceed the capacity of the reservoir and both old and new evaporation ponds.

On an emergency basis consistent with the available time until spring runoff, construction was initiated to clay line an additional 68 acres of old unused evaporation ponds and construct an additional 34 acres of new evaporation ponds to give an additional 715 acre-feet of storage. A new treatment system was constructed and diversion facilities installed to treat nonmineralized pit and north ore shaft water and discharge to the Jordan River (Figure 7). Pumping and pipeline facilities were constructed to discharge seepage being collected in the new evaporation ponds to the Jordan River. The rate of treatment of excess mineralized water was increased substantially by modifying the lime handling and slaking operation. Figure 8 shows the rate of treatment from October 1983 through June 1984.

An application for an NPDES permit was made and a status report of the pending emergency conditions presented to the State of Utah Bureau of Water Pollution and EPA Region 8 on February 13, 1984.

Record precipitation in April of 1984 substantially increased the snowpack on the Bingham watershed and generated a potential for an uncontrolled situation during peak runoff when the snowpack melted. Heavy earth-moving equipment was placed on standby on location to handle emergencies associated with a potentially high rate of runoff.

The spring snowmelt and subsequent runoff started during April 1984. By April 28, the reserve capacity in the reservoir was used (Figure 9) and the rate of runoff exceeded the treatment system capacity resulting in a mixture of treated and untreated water flowing into the evaporation ponds. Except for two days to accommodate construction activity, the combined flow of treated and untreated water was routed into the new clay-lined evaporation ponds. The high rate of flow to the evaporation ponds required emergency work to construct a backup dike across Bingham Canyon and substantially enlarging the diversion canal.

Pumping of seepage water collected in the new evaporation ponds to the Jordan River was started on May 2. By May 25, all of the new evaporation ponds were full except for one being held as a final contingency to contain collected seepage. The flow of excess water was routed back into the old evaporation ponds having limited seepage due to deposition of sludge and construction initiated to raise the dike six feet around five ponds. By June 8, it was evident the amount of excess water could not be contained in the evaporation ponds even with pumping seepage to the Jordan River. As a final contingency control measure, 6,000 GPM of excess runoff was diverted into the mine pit. This control action has had a substantial adverse impact on mining operations.

On June 9, diversion of untreated water around the reservoir was stopped. Diversion of excess water into the mine pit was stopped on June 22 and pumping of seepage water to the Jordan River was stopped on June 24. Treatment of excess mine water utilizing evaporation in the ponds for holding capacity is continuing through the summer to prevent overflow of the reservoir. Figure 10 shows the amount of treated and untreated excess water routed to the evaporation ponds in the 1984 water year compared to prior years, and Figure 11 shows the cumulative amount of treated and untreated excess water routed to the evaporation ponds for the period October 1983 through June 1984. Water quality data is contained in Appendix II.

Environmental Assessment

The excess water treatment and control strategy implemented in 1983-84 was designed to minimize any potential environmental impact. The maximum amount of excess water was treated consistent with lime handling facilities and lime availability during the winter months and impounded in clay-lined evaporation ponds to prevent any potential impact on groundwater quality.

The available area selected for construction of the new evaporation ponds was core drilled to establish the depth and consistency of the underlying clay layer, and the clay from the core drilling was subjected to permeability tests to establish suitability. The pond dikes were constructed in six-inch compacted layers and the base of each pond compacted. The pond dikes were constructed to hold a maximum depth of seven feet with five feet of freeboard. Following construction, the dikes were evaluated to establish structural integrity. Appendix III gives the results of this evaluation. The complete pond area was fenced to minimize any potential safety hazard to children in the adjacent community, and all disturbed areas were vegetated to minimize erosion and fugitive dust.

In order to determine if any potential impact on groundwater could occur from the use of the evaporation ponds, five private wells adjacent and down gradient from the ponds were selected for monthly sampling and analysis. The results of these samples (Appendix II) show no impact has occurred through July 1984. Even though no impact is expected, the monthly monitoring of these wells will continue for an indefinite period.

Figure 1

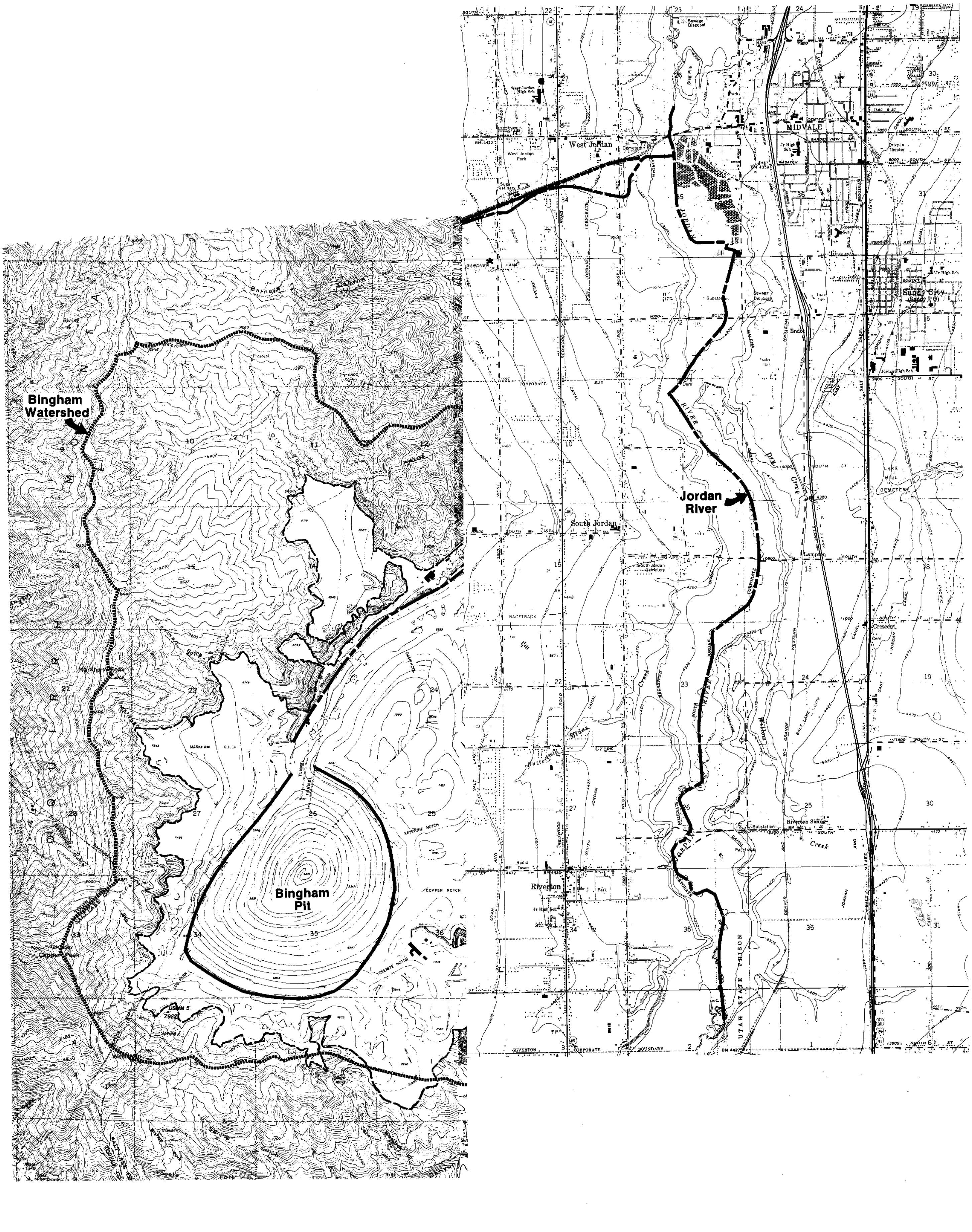

Bingham Watershed
Bingham Pit
Jordan River
MIDVALE
West Jordan
South Jordan
Riverton
Sandy City

Figure 2

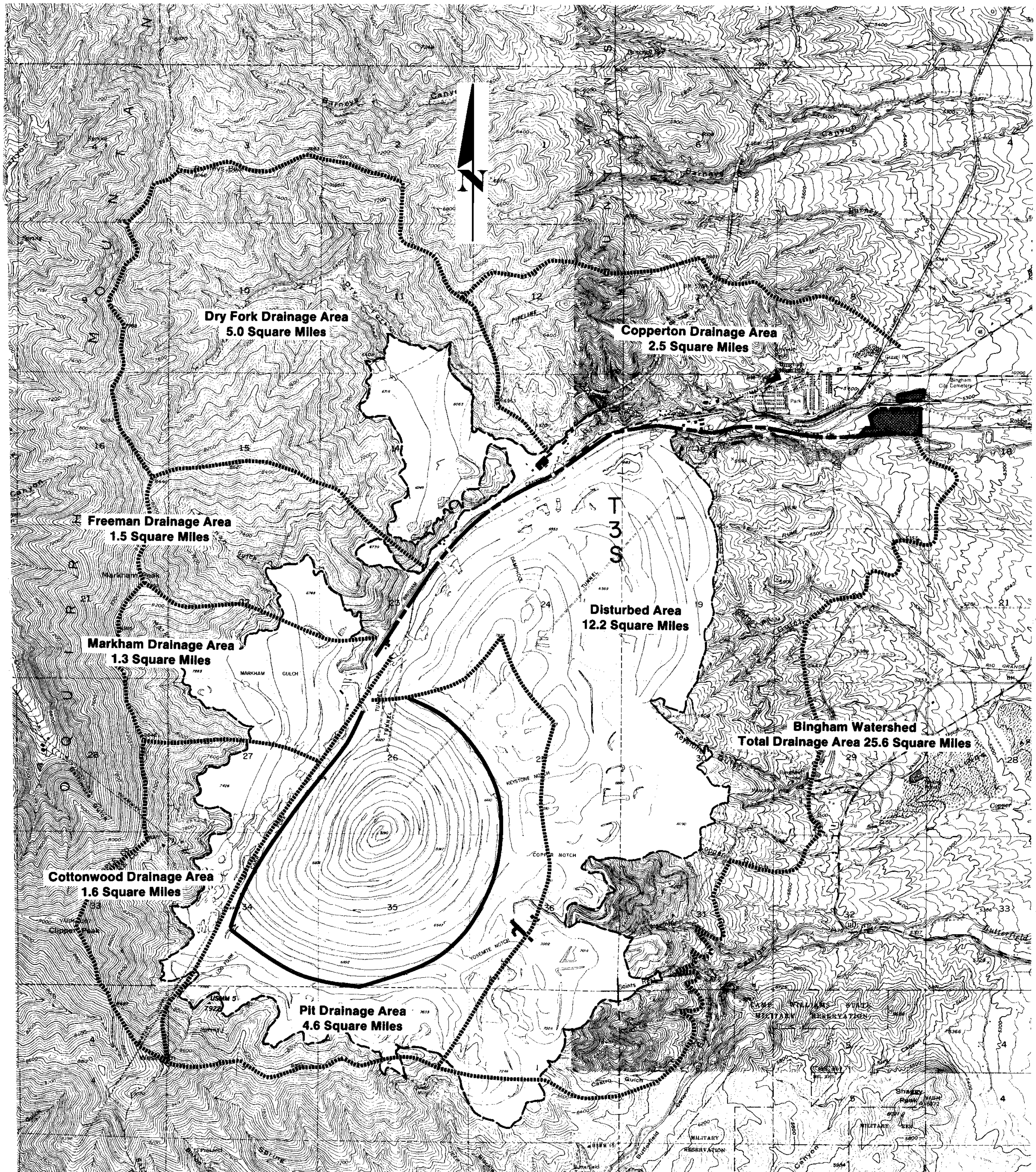
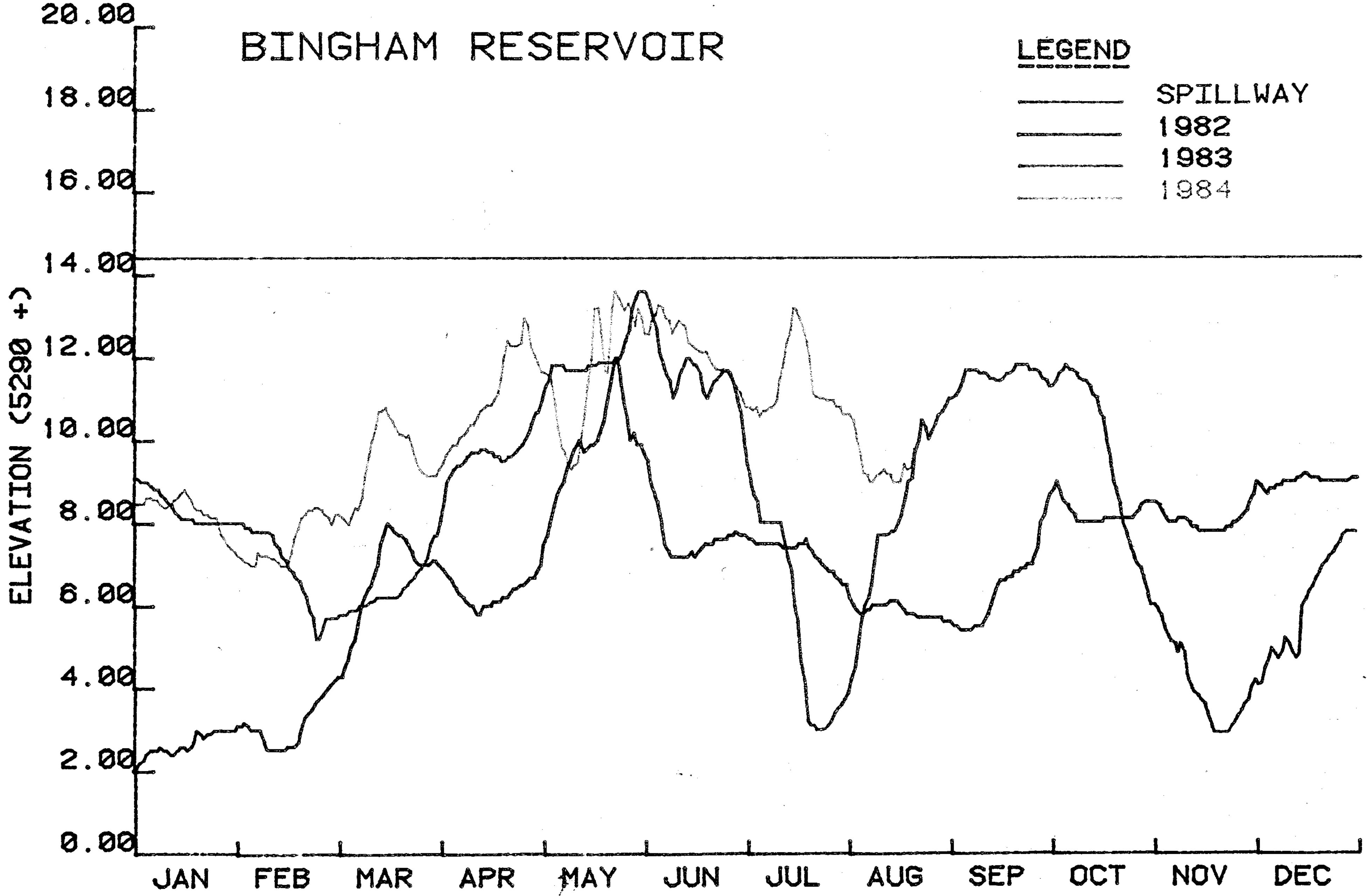

Dry Fork Drainage Area
5.0 Square Miles
Copperton Drainage Area
2.5 Square Miles
Freeman Drainage Area
1.5 Square Miles
Disturbed Area
12.2 Square Miles
Markham Drainage Area
1.3 Square Miles
Bingham Watershed
Total Drainage Area 25.6 Square Miles
Cottonwood Drainage Area
1.6 Square Miles
Pit Drainage Area
4.6 Square Miles
T
3
S
N

Figure 3



BINGHAM RESERVOIR
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SPILLWAY
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1984
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14.00
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NOV
DEC

Figure 4

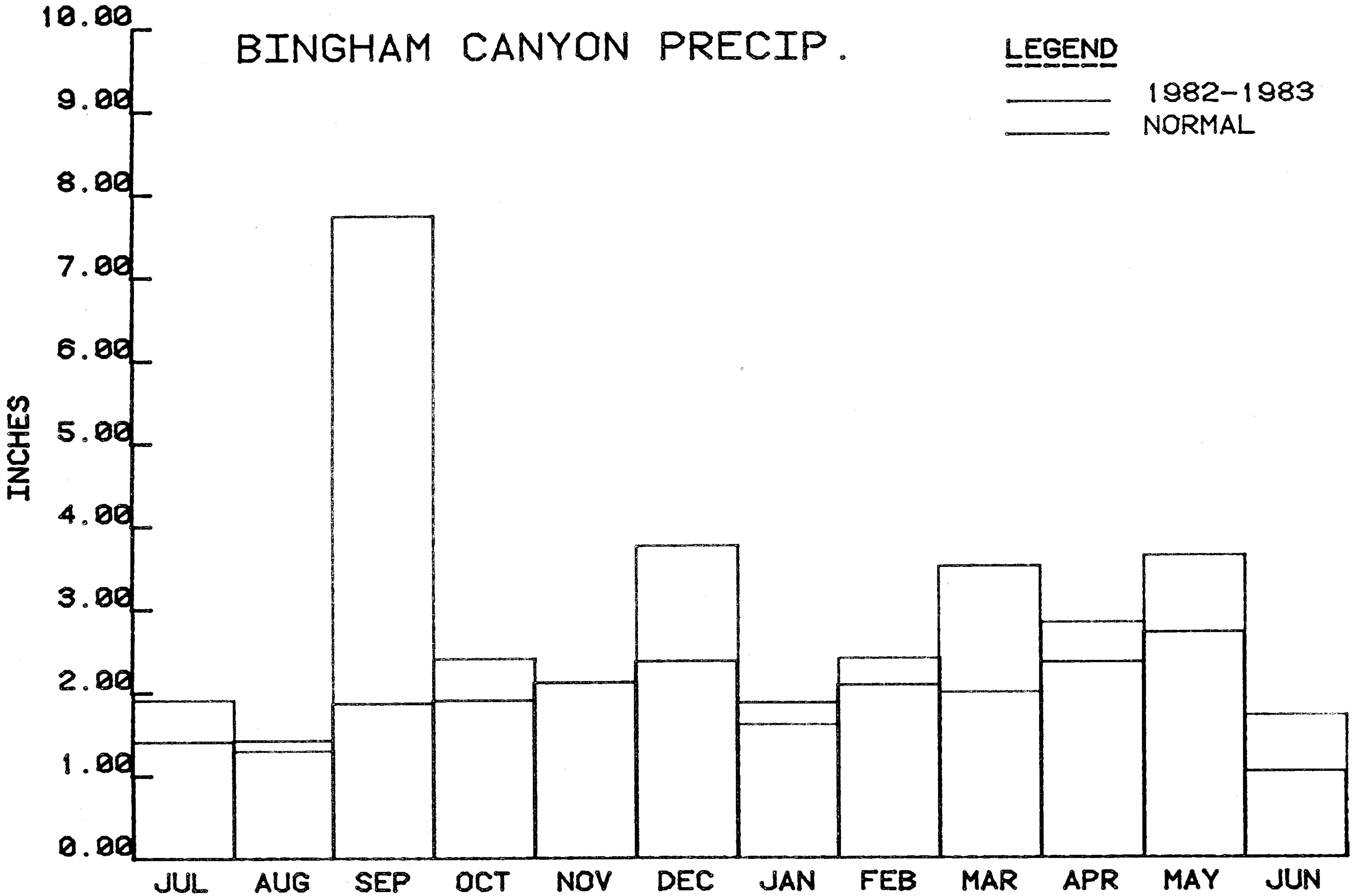
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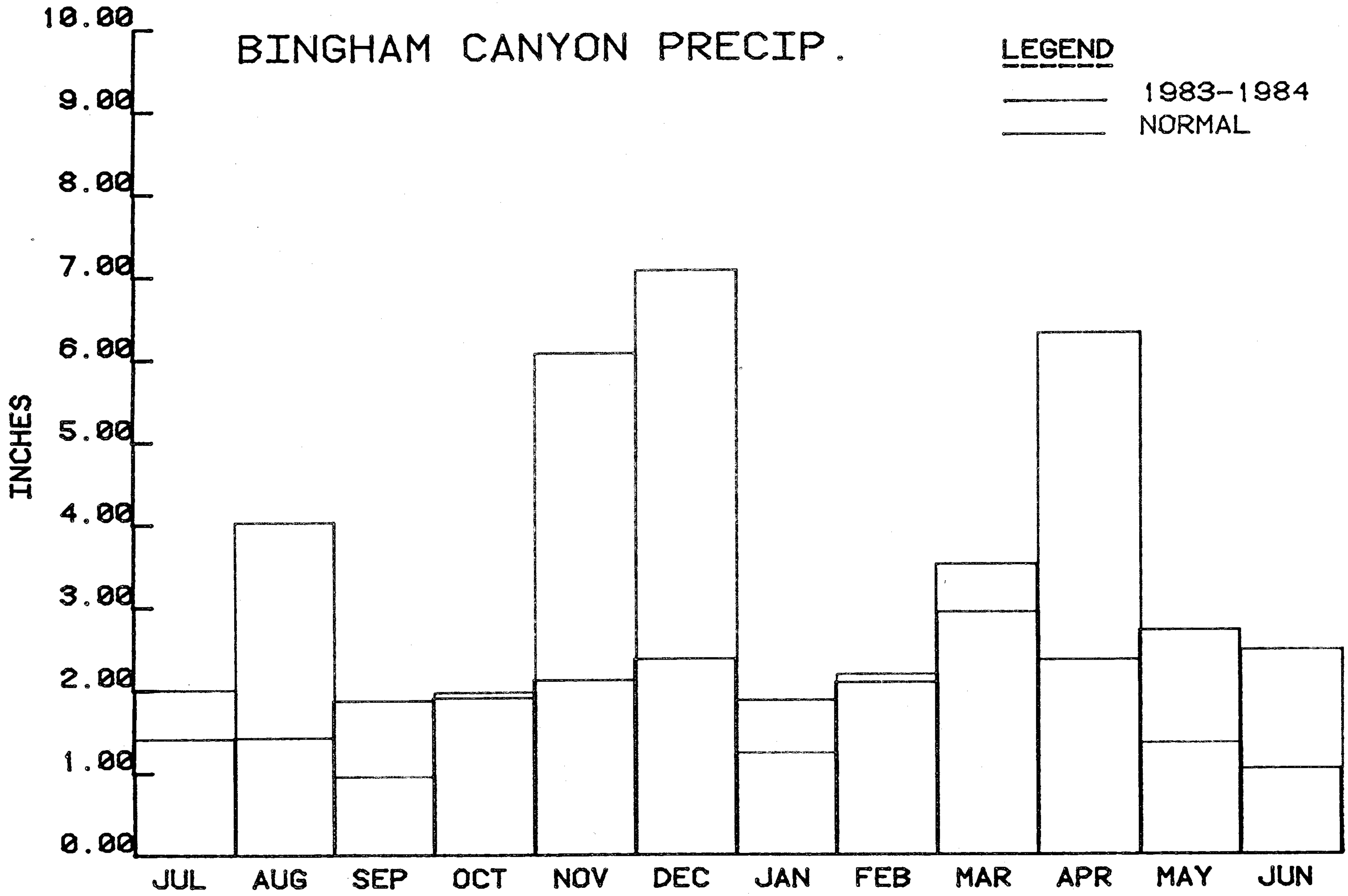
Figure 5


BINGHAM CANYON PRECIP.
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1983-1984
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KENNECOTT
UTAH COPPER DIVISION MINE

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RECEIVED
SEP 1 0 1984
DIVISION OF OIL
GAS & MINING

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$$\text{Leach water} - \frac{35{,}000 \text{ GPM} \times 1{,}440 \text{ minutes}}{326{,}700 \text{ gal./acre-foot}} = 154 \text{ acre-feet}$$

Maximum volume of water from a 10-year, 24-hour precipitation event using a 0.3 runoff coefficient:

$$\frac{2.58^{1} \text{ in.} \times (25.6 \text{ sq. mi.} - 4.6 \text{ sq. mi.})^{2} \times 640 \text{ acres/mi.} \times 0.3}{12 \text{ in./ft.}} = 867 \text{ acre-feet}$$

Total needed capacity = 1,034 acre-feet

Capacity of Bingham Canyon drainage facilities:

Large Bingham Creek Reservoir	= 1,500 acre-feet
Small Bingham Creek Reservoir	= 61 acre-feet
Clay-lined evaporation ponds - 182 acres x 7 feet	= 1,274 acre-feet
Old sludge-lined evaporation ponds[3] - 87 acres x 7 feet + 20 acres x 5 feet	= 709 acre-feet
Total actual capacity	= 3,544 acre-feet

[1]Based on the maximum measured 24-hour precipitation on September 26, 1982 measured in the Bingham Canyon during the past ten years. The measured value is an average of six measuring locations in the watershed area.

[2]The total surface area of the Bingham Canyon watershed is 25.6 square miles. Drainage from 4.6 square miles of this area runs into the mine pit where it is contained. Therefore, the net surface area contributing runoff to the Bingham Canyon is 21 square miles.

[3]This does not include approximately 1,900 acre-feet capacity of unlined evaporation ponds. These ponds have little or no deposition of treatment sludge and, therefore, cannot be considered to be effective containment facilities for the purpose of this calculation.

Mining Activity and Geology

The Kennecott Utah Copper Division Bingham Canyon Mine is located in Bingham Canyon on the west side of the Salt Lake Valley. The mining operation consists of open-pit mining of low-grade copper ore, removal of overburden or waste material and dump leaching of the waste material. It was the first open-pit mining operation in the copper industry and presently the largest open-pit mine in the world. Activity associated with the discovery and subsequent development of the mine began in 1863. Mining of the ore body was limited to underground mining techniques until 1906 when open-pit mining was initiated. Over 4,000,000,000 tons of material have been removed since the mining operation commenced.

The mineral deposit is a porphyry copper ore body containing recoverable amounts of copper, molybdenum, selenium, gold, silver and palladium. Most of the metals occur as sulfide minerals which are extracted by a froth flotation process in the copper concentrating operation. The ore body also contains iron sulfides and trace amounts of several other metal sulfides which are not extracted in the concentrating operation.

The classification of bulk material as waste or ore is an economic determination based on the recoverable metal content of the material and existing market conditions. Generally, the ratio of waste to ore in the mined material is about 2:1. The ore is transported to the concentrators for processing and the waste is transported to overburden dumps in the vicinity of the mine.

The overburden dumps are leached to recover soluble copper. The dissolved copper in the leach water is precipitated using scrap iron as the reagent. The leach system is a zero discharge recirculating system with state of the art collection facilities at the base of the overburden dumps. The recirculation rate is 30,000 to 35,000 GPM with the Bingham Creek Reservoir providing surge capacity either to hold normal excess storm water or provide makeup water. The total volume of water in circulation at any given time is about 1,500 acre-feet. The uncertainty in this estimated volume is the variable resonance time of the recirculated water in the various overburden dumps. About eleven percent of the copper produced from the Bingham Canyon Mine comes from the leaching operation.

Bingham Canyon Watershed and Historical Water Management

Bingham Canyon is located on the east slope of the Oquirrh Mountains. The watershed covers a 25.6 square mile area ranging in elevation from 5300' to 9200'. Historically, drainage from the watershed due to rainfall and spring snowmelt flowed from the canyon east through the Salt Lake Valley into the Jordan River which terminates in the Great Salt Lake (Figure 1). Depending on climatic conditions, the annual precipitation on the Bingham Canyon watershed area averages 24.6 inches with a measured accumulated snowpack averaging 50 inches. Most of the surface runoff from the watershed is due to melting of the accumulated snowpack in the spring.

At the present time, 12.2 square miles of the watershed are covered by mining operations and 13.4 square miles are undisturbed mountain area. Due to the nature of historical mining development, all surface runoff from undisturbed areas except for the actual mine pit area flows through disturbed areas mixing with recirculated leach water and is collected by the leach water collection system (Figure 2).

Surface runoff water which comes in contact with the disturbed ore body becomes acidic and mineralized due to the natural oxidation and dissolution of minerals contained in the ore body. Recognizing the potential to extract dissolved copper from this water, nonrecycle copper precipitation is believed to have been started before 1900. As the surface area of mine waste dumps increased, recycle of water to the dumps was initiated and full-scale copper precipitation operations had become a substantial means of copper production by 1923.

Historically, excess water from copper precipitation operations as well as direct runoff flowed in Bingham Creek to the Jordan River.[1] Evidence shows the mineralized water was occasionally diverted out of Bingham Creek onto open areas to prevent contamination of irrigation canals from the Jordan River which intercept Bingham Creek.

[1] Kennecott, in cooperation with the Utah Division of Environmental Health and Salt Lake County, initiated an extensive five-year groundwater study in 1983 to determine the impact of historical and present mining activity on groundwater between the Bingham Canyon and the Jordan River.

In the 1930's, evaporation ponds were constructed five miles west of Bingham Canyon to contain the mineralized water flowing out of the canyon. These ponds were constructed on a level area which was a historic river delta created by Bingham Creek when Lake Bonneville existed. Because the river delta is a deposit of composite materials overlaying sedimentary clay material on the valley floor, use of the evaporation ponds resulted in seepage from the ponds surfacing at the face of the delta.

In 1965, the Bingham Creek Reservoir was constructed to contain all surface runoff from the Bingham Canyon watershed and provide adequate surge capacity for the leach water recirculation system as well as a source of makeup water for the leaching operation. The 1,500 acre-feet capacity of the reservoir has been sufficient to contain storm water runoff from the Bingham Canyon watershed except for a small amount of excess water during 1973, 1974 and 1975 which was diverted around the reservoir to the evaporation ponds to prevent an uncontrolled overflow of the reservoir.

The reservoir water level increased again during the winter of 1981-82 due to heavy precipitation (Figure 3). To avoid reservoir overflow when the spring runoff occurred, facilities were constructed to route nonmineralized water being pumped from the mine pit and water from the north ore shaft around the reservoir to the evaporation ponds. This diversion, along with increased recirculation to the west side leach dumps during peak runoff, was sufficient to avoid having to discharge excess mineralized water to the evaporation ponds.

Record precipitation during September 1982 and heavy snowfall during the winter of 1982-83 increased the reservoir water level to a point that it was evident the spring runoff would exceed the reservoir capacity (Figure 4). In an attempt to avoid the discharge of leach water to the evaporation ponds, emergency lime treatment facilities were installed to treat excess leach water in March 1983. Between April 20, 1983 and July 17, 1983, 960 acre-feet of leach water were treated, but the amount treated and discharged to the evaporation ponds was insufficient to accommodate the necessary capacity in the reservoir to contain the spring runoff. As a result, 695 acre-feet of untreated water were diverted around the reservoir to the evaporation ponds. The total volume of excess storm water for the 1982-83 water year was 1,655 acre-feet.

The diversion of untreated water around the reservoir was initiated prior to the peak runoff when it became evident the reservoir capacity would be exceeded. Allowing the reservoir to fill to overflow would result in uncontrolled discharge from the spillway which could exceed the structure which diverts the discharge out of the Bingham drainage into a canal going to the evaporation ponds. Overflowing this diversion structure would result in mineralized water flowing down the Bingham drainage which no longer exists as an actual drainage due to residential development in the drainage.

Storm Water Management (July 1, 1983 to June 30, 1984)

As the result of diverting a record amount of excess mine water into the evaporation ponds during the spring of 1983 combined with excessive precipitation during the summer of 1983, substantial seepage occurred at the base of the river delta below the evaporation ponds. The initial seepage accumulated in an abandoned gravel pit on the south side of the delta. During a heavy rainstorm in August 1983 (Figure 5), the seepage exceeded the capacity of the gravel pit and flowed off Kennecott property into the Provo Reservoir Water Users Association Canal.

On an emergency basis, a barrier trench and two small holding ponds were constructed to intercept and contain the seepage flowing into the canal. This discharge was stopped within 24 hours and reported to the appropriate environmental authorities.

Continued diversion of excess mine water into the evaporation ponds and heavy precipitation in September 1983 resulted in additional seepage from the east side of the delta and a substantial increase in the seepage from the south side. On an emergency basis, 79 acres of evaporation ponds having 556 acre-feet capacity were constructed on the south side of the river delta in the underlying clay layer to contain the seepage. Barrier trenches and a holding pond were constructed to collect the seepage from the east side. Pumping facilities and a pipeline were installed to route the water collected on the east side into the new evaporation ponds constructed on the south side (Figure 6). Except for riprap on the largest evaporation pond and land reclamation, the construction of these facilities was completed by December 31, 1983 with all seepage being contained on Kennecott property.

In anticipation of another year of record spring runoff in 1984, treatment of excess mine water was initiated in October 1983 to generate capacity in the reservoir for the spring runoff. The anticipated precipitation materialized when record snowfall occurred during November and December 1983. A survey of the accumulated snowpack and existing remaining reservoir capacity in January 1984 showed the spring runoff would exceed the capacity of the reservoir and both old and new evaporation ponds.

On an emergency basis consistent with the available time until spring runoff, construction was initiated to clay line an additional 68 acres of old unused evaporation ponds and construct an additional 34 acres of new evaporation ponds to give an additional 715 acre-feet of storage. A new treatment system was constructed and diversion facilities installed to treat nonmineralized pit and north ore shaft water and discharge to the Jordan River (Figure 7). Pumping and pipeline facilities were constructed to discharge seepage being collected in the new evaporation ponds to the Jordan River. The rate of treatment of excess mineralized water was increased substantially by modifying the lime handling and slaking operation. Figure 8 shows the rate of treatment from October 1983 through June 1984.

An application for an NPDES permit was made and a status report of the pending emergency conditions presented to the State of Utah Bureau of Water Pollution and EPA Region 8 on February 13, 1984.

Record precipitation in April of 1984 substantially increased the snowpack on the Bingham watershed and generated a potential for an uncontrolled situation during peak runoff when the snowpack melted. Heavy earth-moving equipment was placed on standby on location to handle emergencies associated with a potentially high rate of runoff.

The spring snowmelt and subsequent runoff started during April 1984. By April 28, the reserve capacity in the reservoir was used (Figure 9) and the rate of runoff exceeded the treatment system capacity resulting in a mixture of treated and untreated water flowing into the evaporation ponds. Except for two days to accommodate construction activity, the combined flow of treated and untreated water was routed into the new clay-lined evaporation ponds. The high rate of flow to the evaporation ponds required emergency work to construct a backup dike across Bingham Canyon and substantially enlarging the diversion canal.

Pumping of seepage water collected in the new evaporation ponds to the Jordan River was started on May 2. By May 25, all of the new evaporation ponds were full except for one being held as a final contingency to contain collected seepage. The flow of excess water was routed back into the old evaporation ponds having limited seepage due to deposition of sludge and construction initiated to raise the dike six feet around five ponds. By June 8, it was evident the amount of excess water could not be contained in the evaporation ponds even with pumping seepage to the Jordan River. As a final contingency control measure, 6,000 GPM of excess runoff was diverted into the mine pit. This control action has had a substantial adverse impact on mining operations.

On June 9, diversion of untreated water around the reservoir was stopped. Diversion of excess water into the mine pit was stopped on June 22 and pumping of seepage water to the Jordan River was stopped on June 24. Treatment of excess mine water utilizing evaporation in the ponds for holding capacity is continuing through the summer to prevent overflow of the reservoir. Figure 10 shows the amount of treated and untreated excess water routed to the evaporation ponds in the 1984 water year compared to prior years, and Figure 11 shows the cumulative amount of treated and untreated excess water routed to the evaporation ponds for the period October 1983 through June 1984. Water quality data is contained in Appendix II.

Environmental Assessment

The excess water treatment and control strategy implemented in 1983-84 was designed to minimize any potential environmental impact. The maximum amount of excess water was treated consistent with lime handling facilities and lime availability during the winter months and impounded in clay-lined evaporation ponds to prevent any potential impact on groundwater quality.

The available area selected for construction of the new evaporation ponds was core drilled to establish the depth and consistency of the underlying clay layer, and the clay from the core drilling was subjected to permeability tests to establish suitability. The pond dikes were constructed in six-inch compacted layers and the base of each pond compacted. The pond dikes were constructed to hold a maximum depth of seven feet with five feet of freeboard. Following construction, the dikes were evaluated to establish structural integrity. Appendix III gives the results of this evaluation. The complete pond area was fenced to minimize any potential safety hazard to children in the adjacent community, and all disturbed areas were vegetated to minimize erosion and fugitive dust.

In order to determine if any potential impact on groundwater could occur from the use of the evaporation ponds, five private wells adjacent and down gradient from the ponds were selected for monthly sampling and analysis. The results of these samples (Appendix II) show no impact has occurred through July 1984. Even though no impact is expected, the monthly monitoring of these wells will continue for an indefinite period.

Figure 1

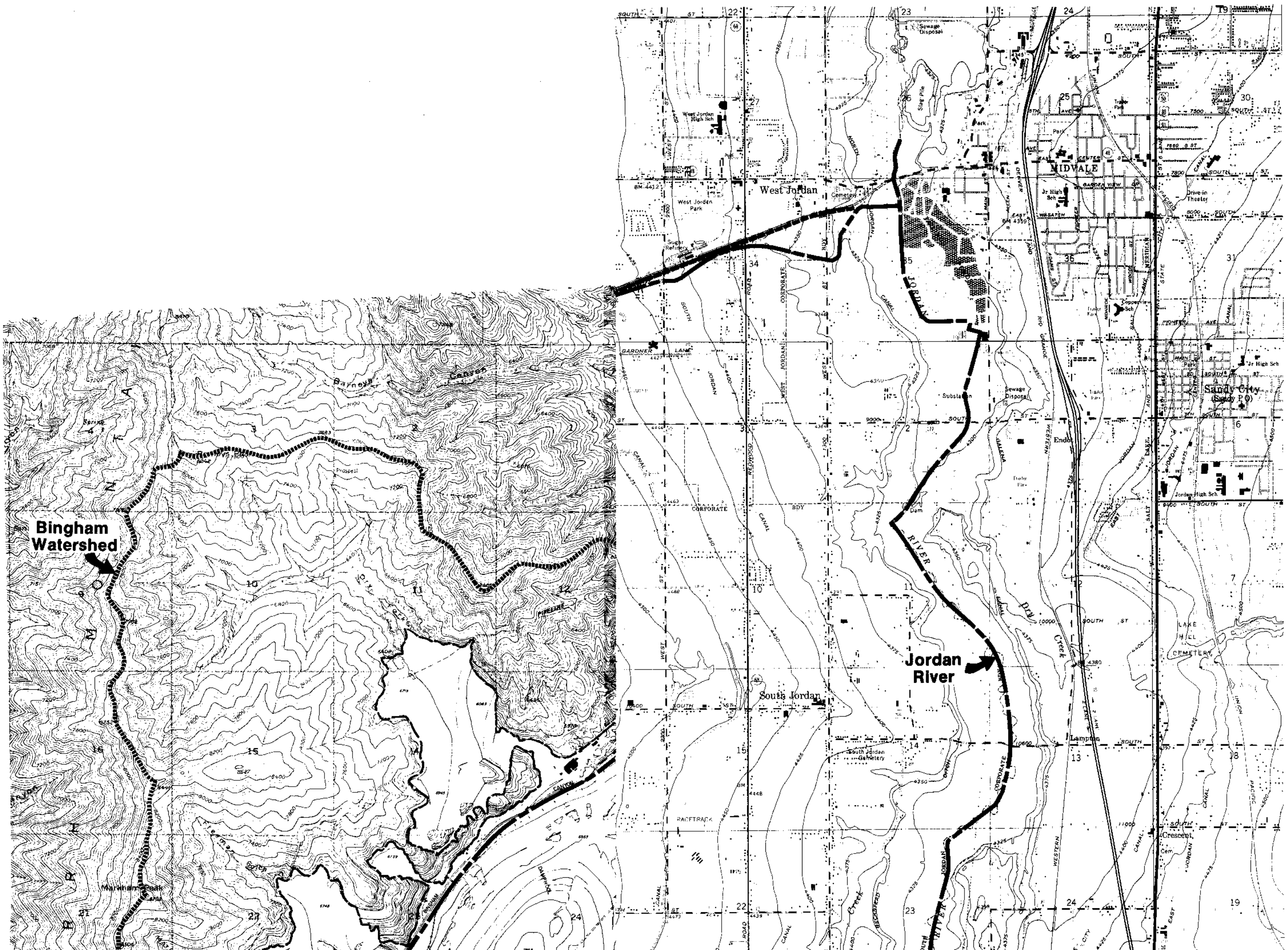
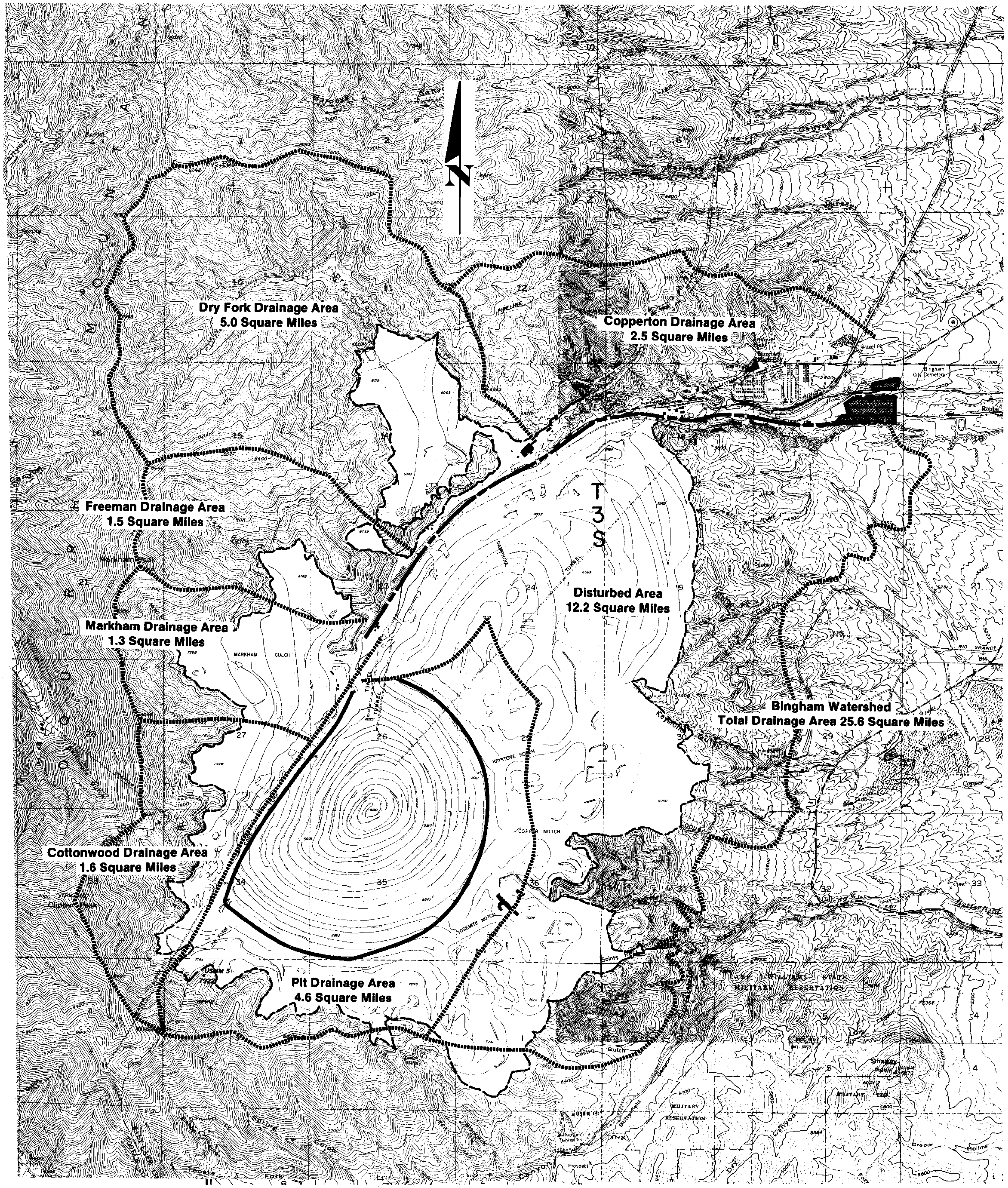

Bingham Watershed
Bingham Pit
Jordan River
West Jordan
MIDVALE
South Jordan
Riverton
Sandy City

Figure 2



N
Dry Fork Drainage Area
5.0 Square Miles
Copperton Drainage Area
2.5 Square Miles
Freeman Drainage Area
1.5 Square Miles
Markham Drainage Area
1.3 Square Miles
Disturbed Area
12.2 Square Miles
T
3
S
Bingham Watershed
Total Drainage Area 25.6 Square Miles
Cottonwood Drainage Area
1.6 Square Miles
Pit Drainage Area
4.6 Square Miles

Figure 3

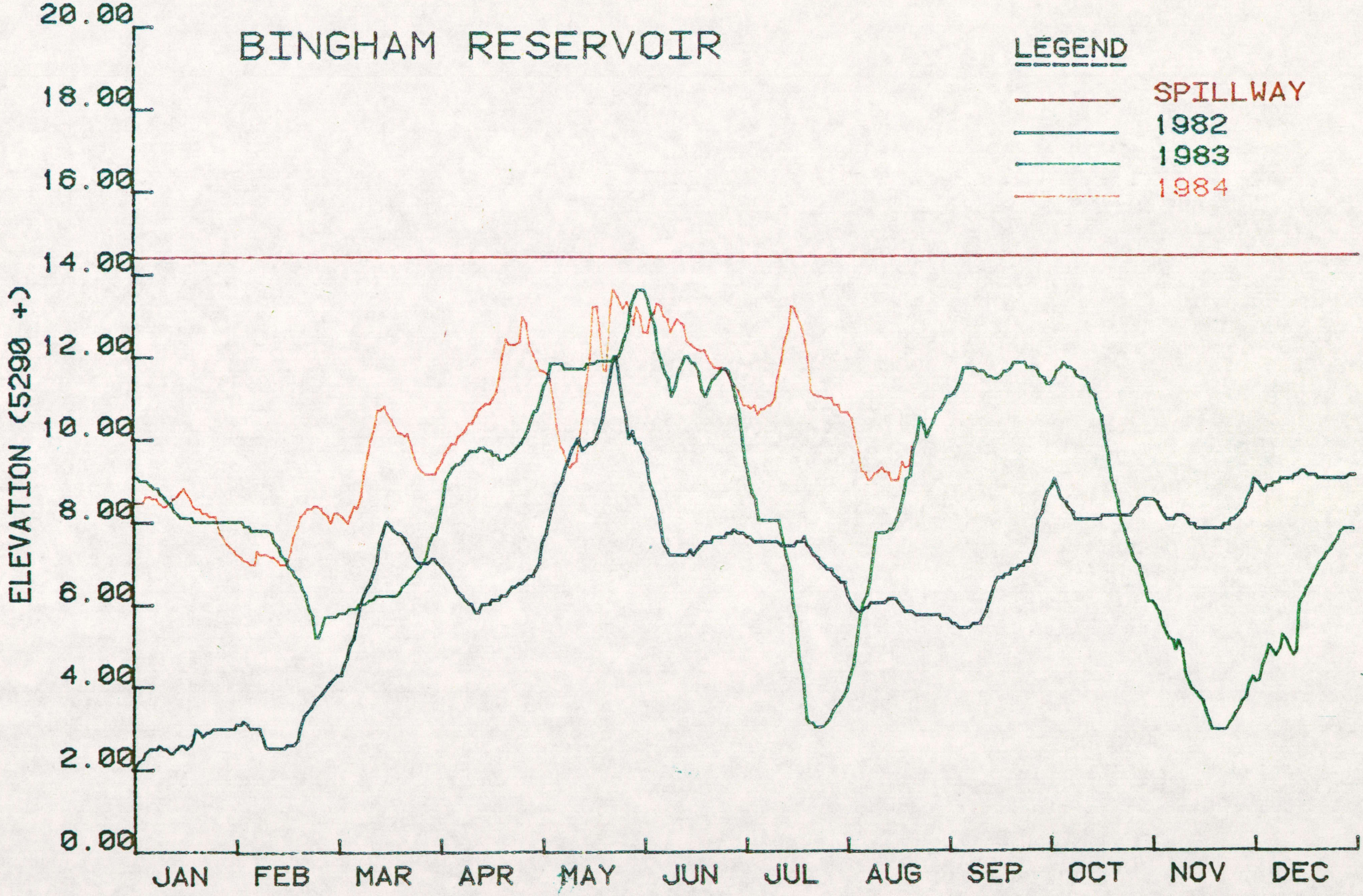

BINGHAM RESERVOIR
LEGEND
SPILLWAY
1982
1983
1984
ELEVATION (5290 +)
20.00
18.00
16.00
14.00
12.00
10.00
8.00
6.00
4.00
2.00
0.00
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

Figure 4

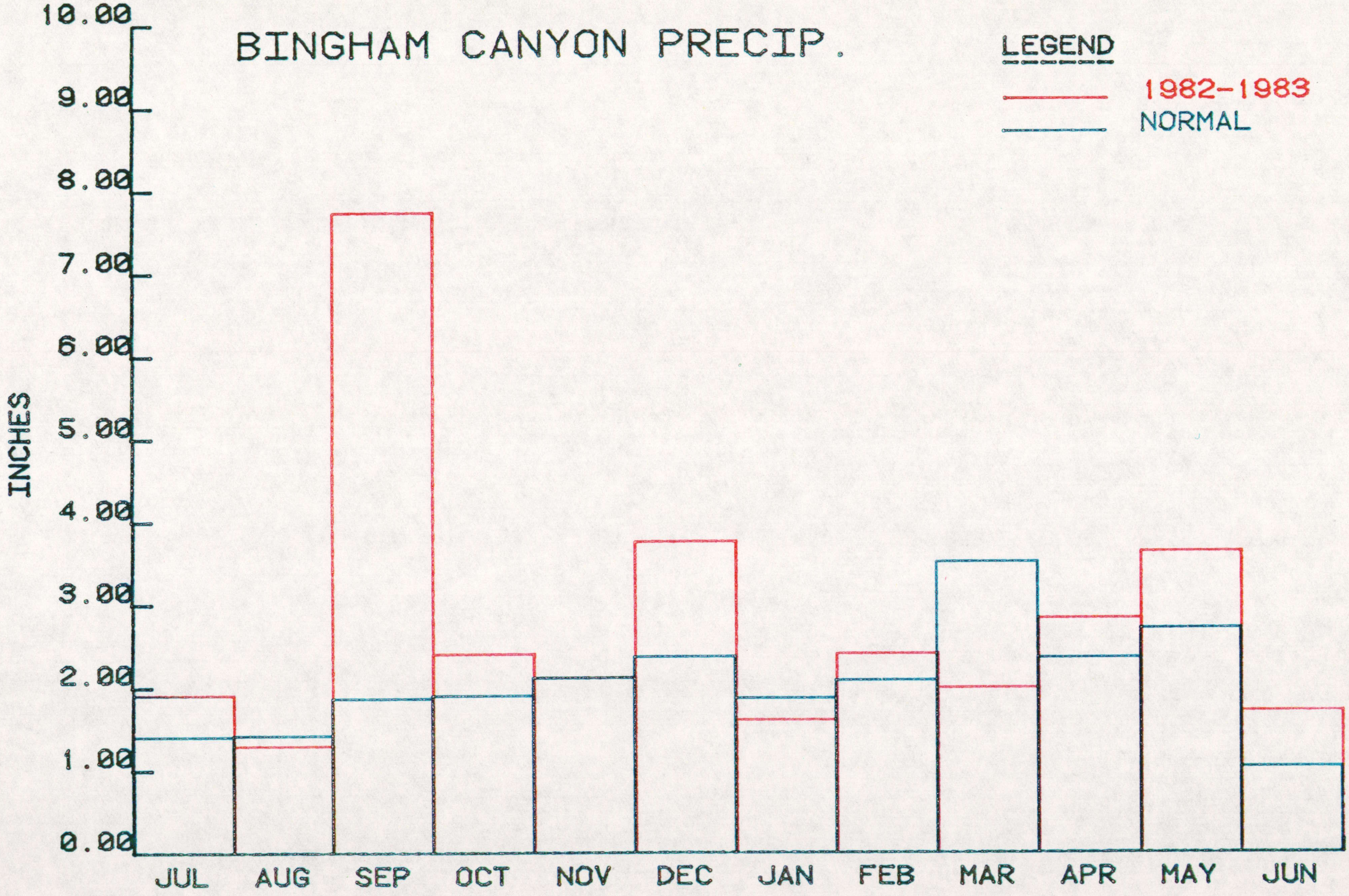
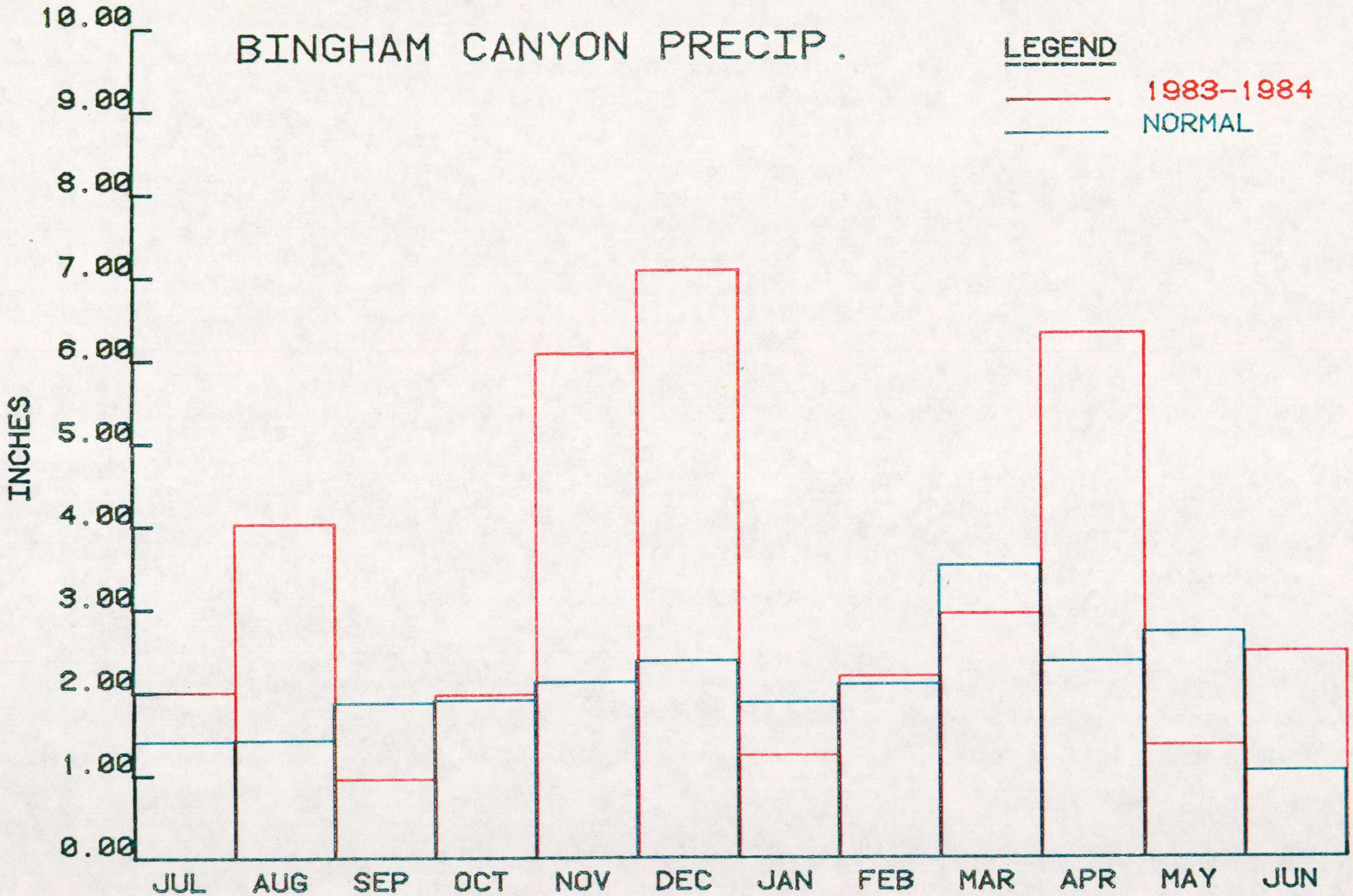
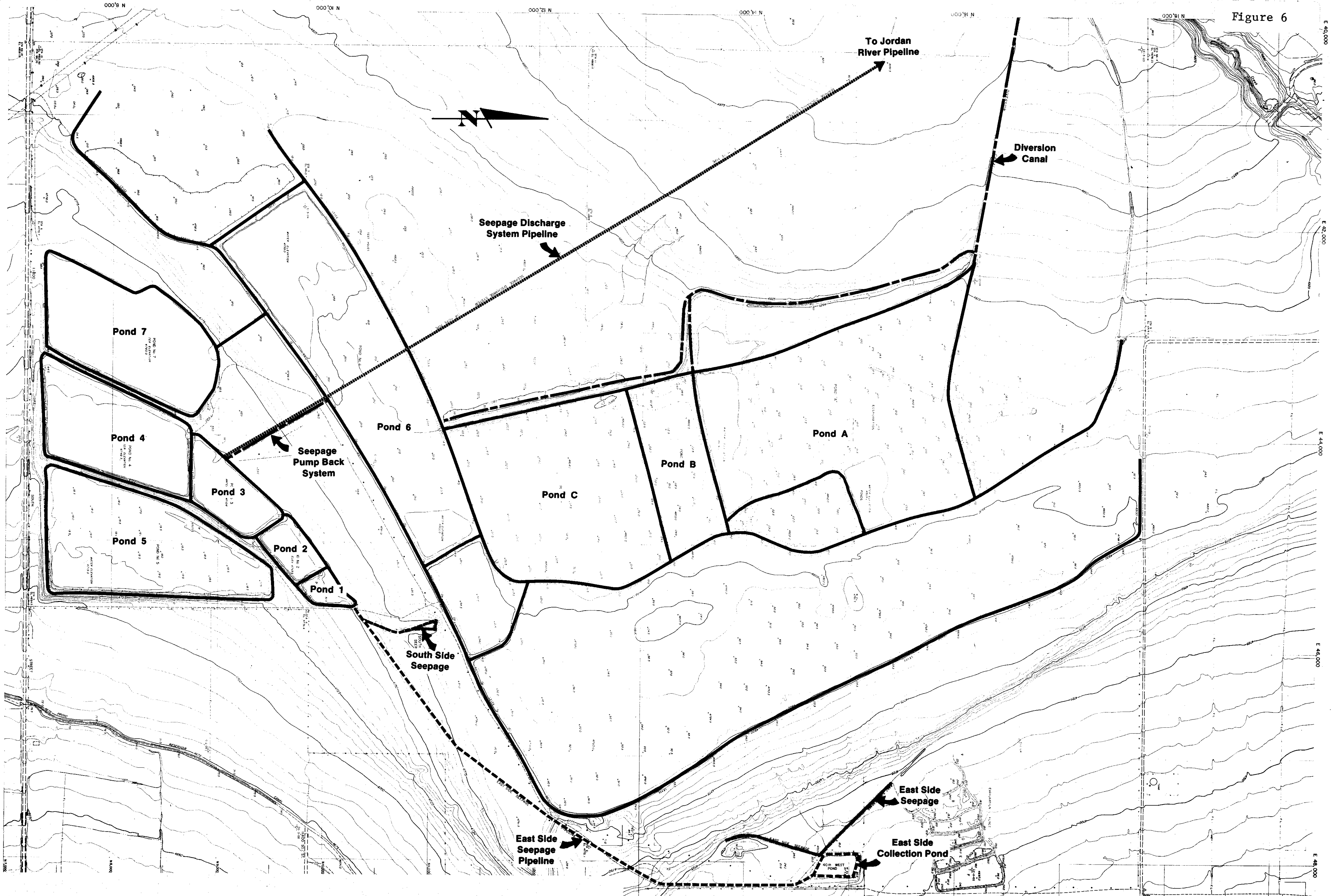

BINGHAM CANYON PRECIP.
LEGEND
1982-1983
NORMAL
INCHES
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN

Figure 5



BINGHAM CANYON PRECIP.
LEGEND
1983-1984
NORMAL
INCHES
10.00
9.00
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
JUL
AUG
SEP
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN



To Jordan River Pipeline
Diversion Canal
Seepage Discharge System Pipeline
Pond 7
Pond 4
Pond 5
Pond 3
Pond 2
Pond 1
Seepage Pump Back System
Pond 6
Pond C
Pond B
Pond A
South Side Seepage
East Side Seepage Pipeline
East Side Seepage
East Side Collection Pond
N

Figure 6

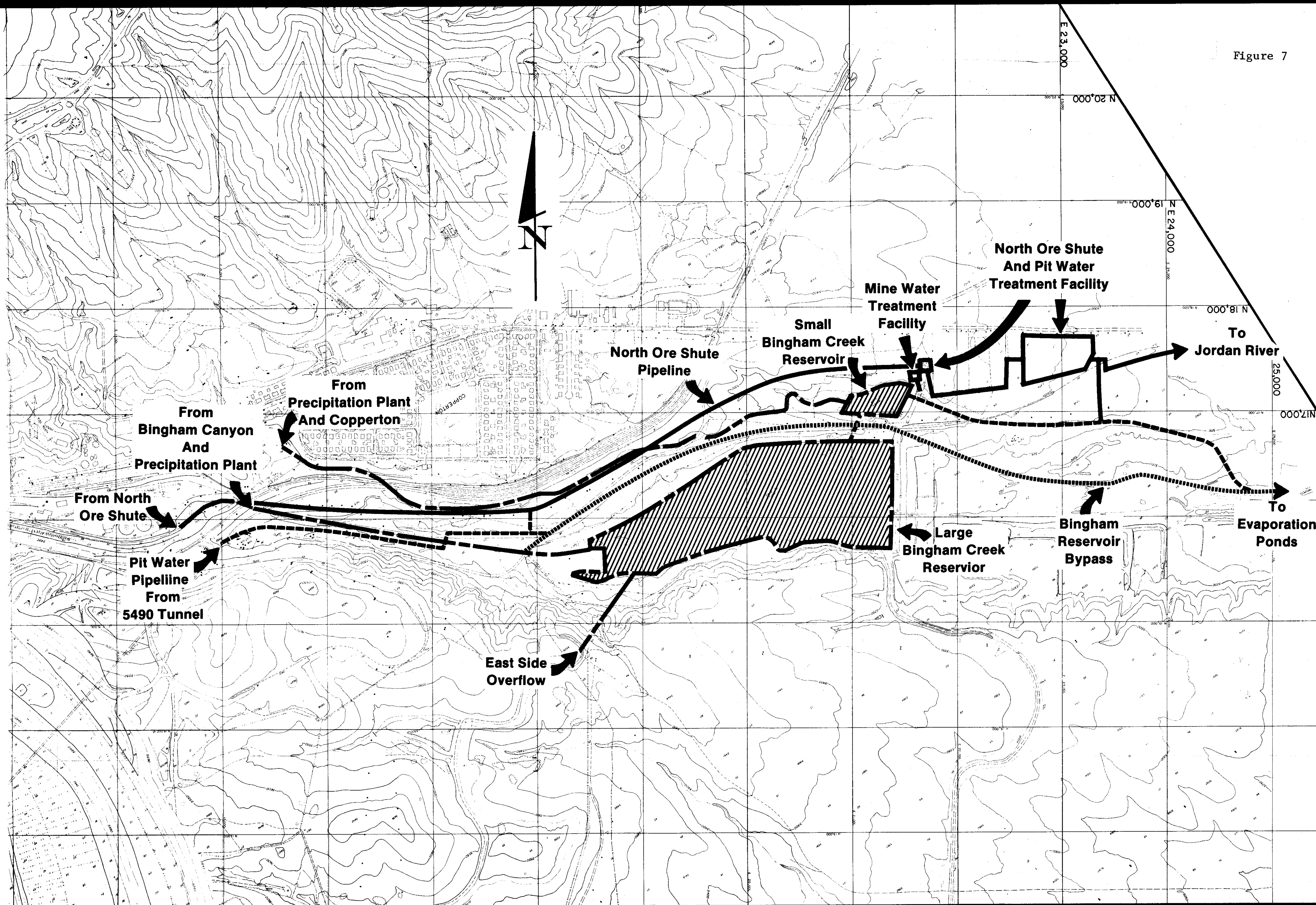

N
North Ore Shute
And Pit Water
Treatment Facility
Mine Water
Treatment
Facility
Small
Bingham Creek
Reservoir
North Ore Shute
Pipeline
To
Jordan River
From
Precipitation Plant
And Copperton
COPPERTON
From
Bingham Canyon
And
Precipitation Plant
From North
Ore Shute
Pit Water
Pipeline
From
5490 Tunnel
To
Evaporation
Ponds
Large
Bingham Creek
Reservior
Bingham
Reservoir
Bypass
East Side
Overflow
E 23,000
E 24,000
N 20,000
N 19,000
N 18,000
N17,000
25,000

Figure 7

Figure 8

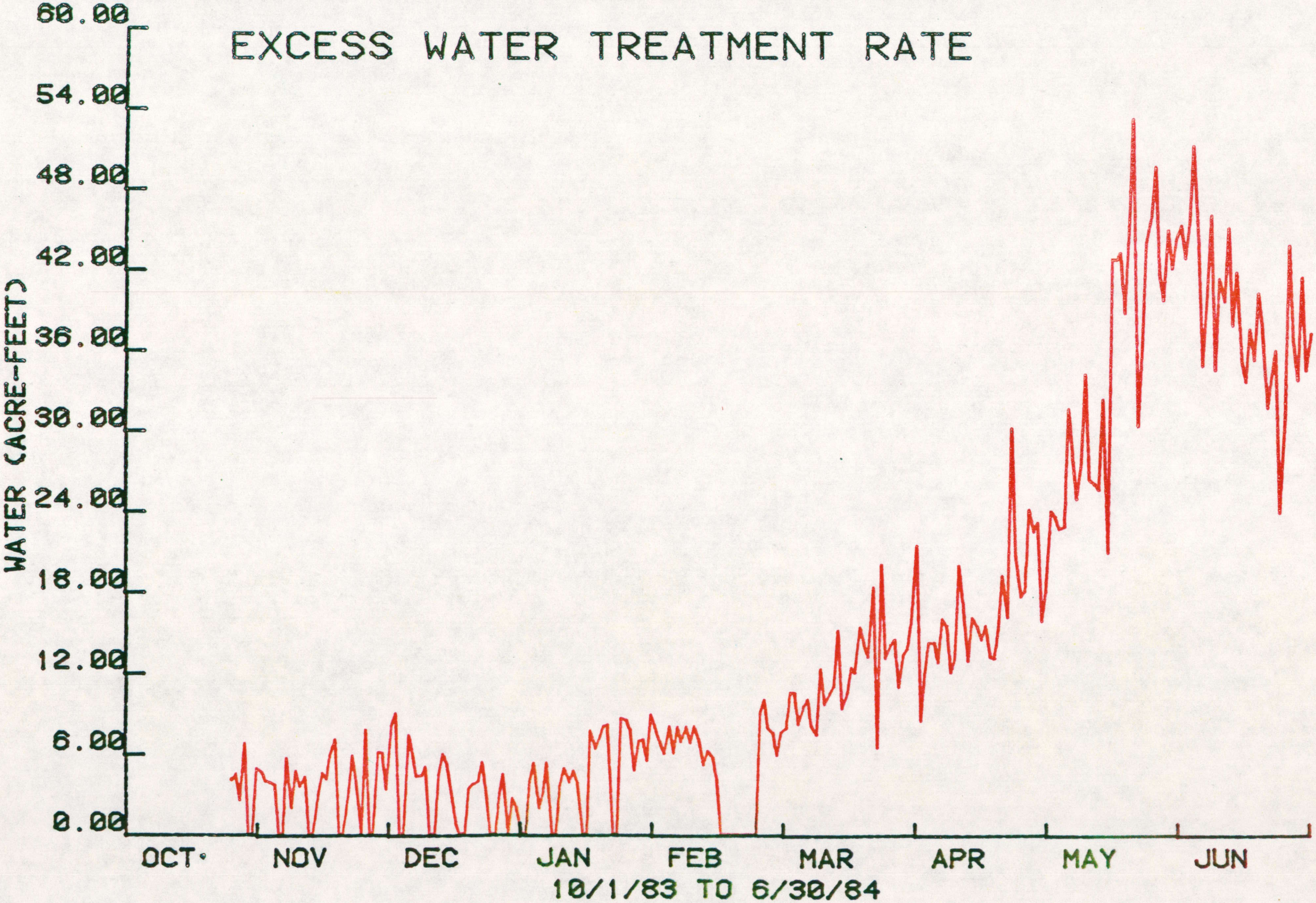
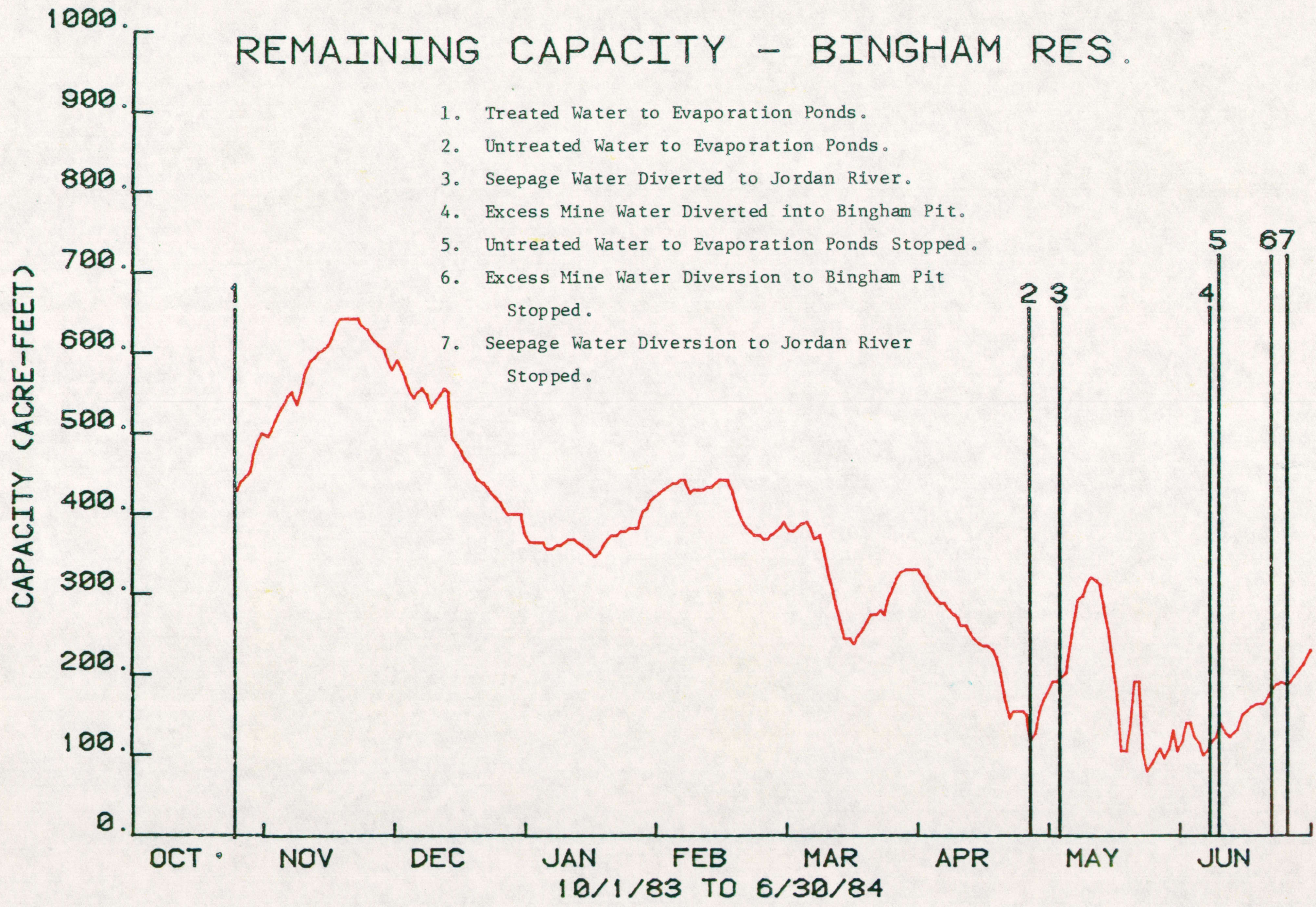
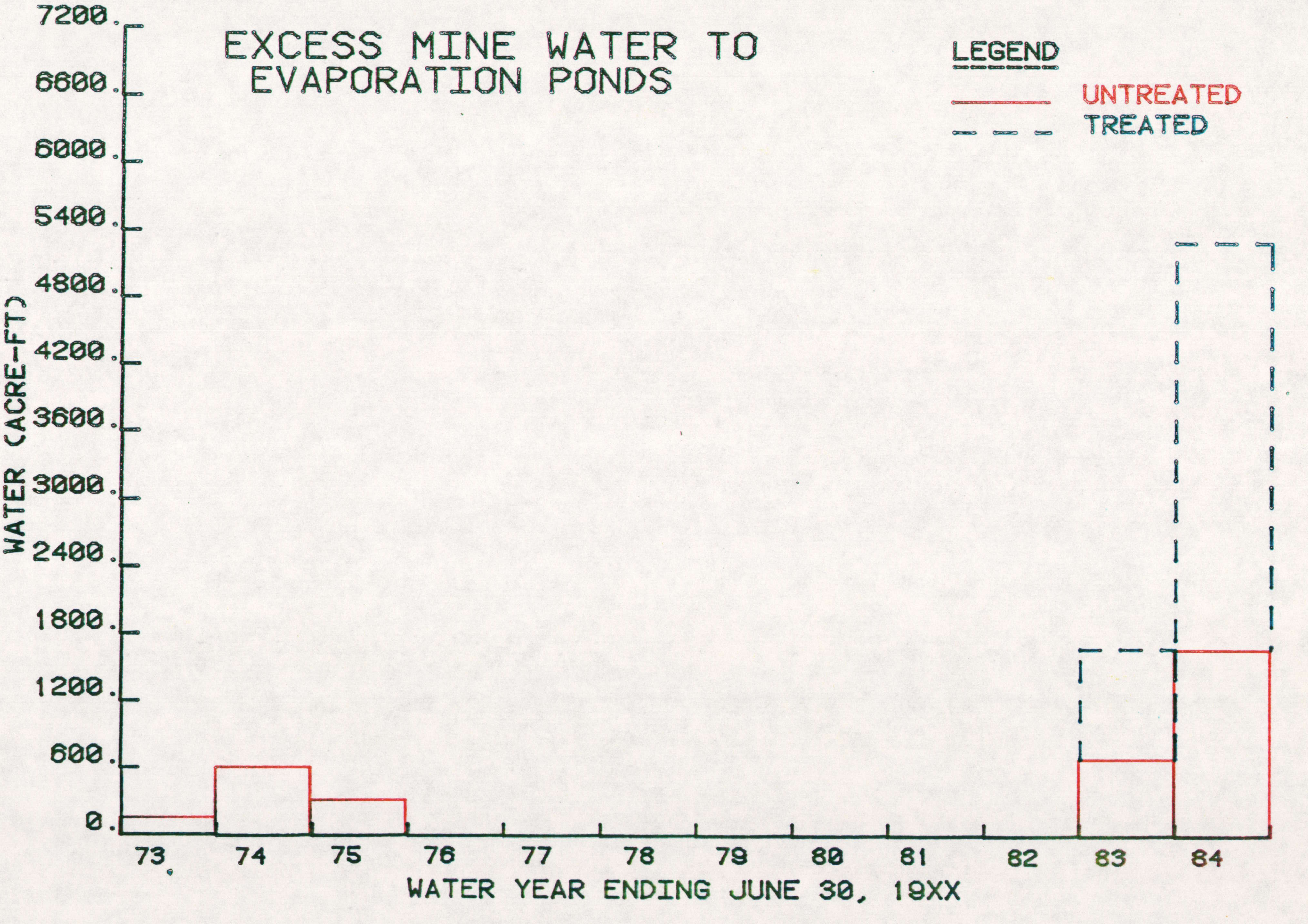

EXCESS WATER TREATMENT RATE
WATER (ACRE-FEET)
60.00
54.00
48.00
42.00
36.00
30.00
24.00
18.00
12.00
6.00
0.00
OCT.
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
10/1/83 TO 6/30/84

Figure 9



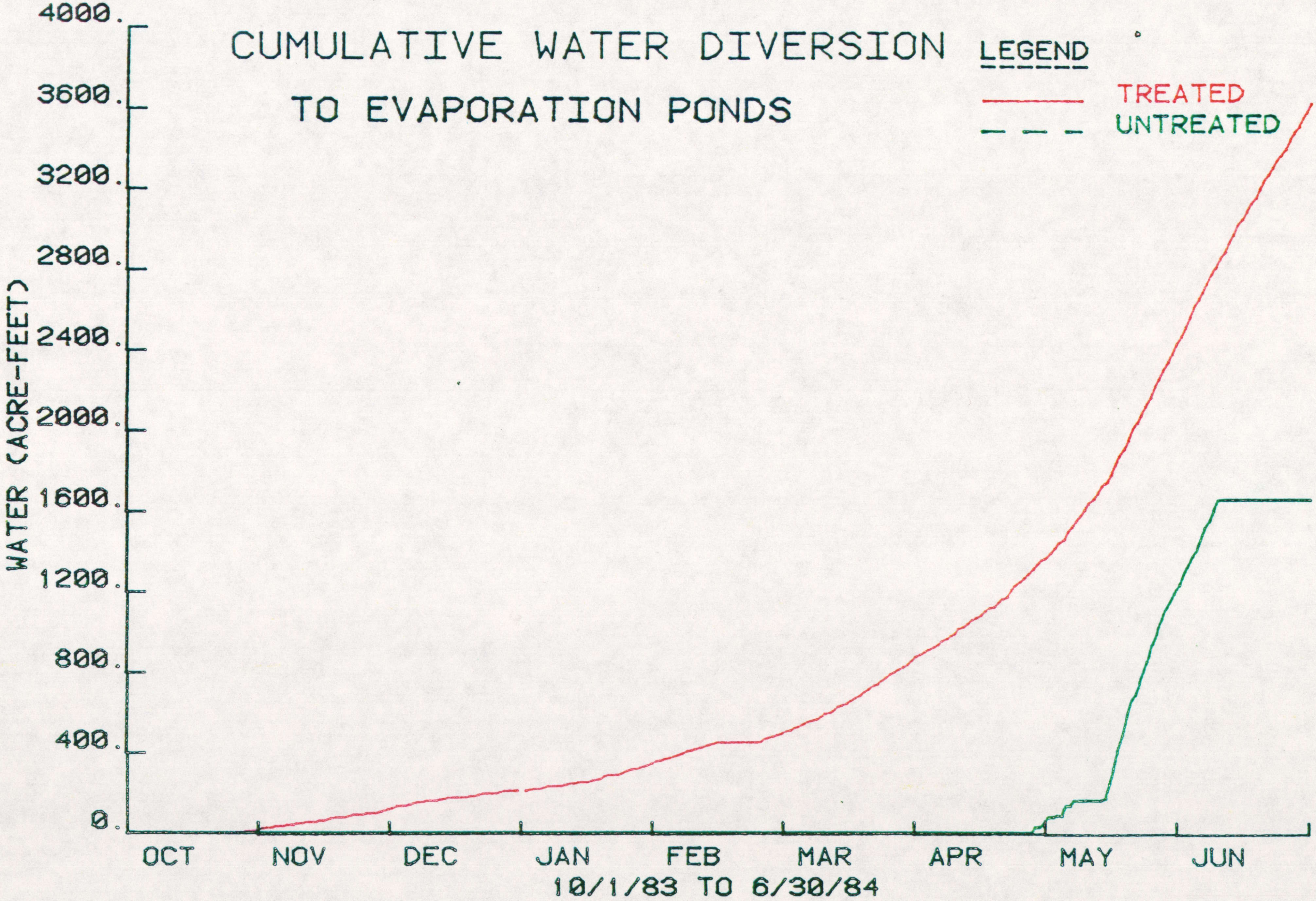
REMAINING CAPACITY - BINGHAM RES.
1. Treated Water to Evaporation Ponds.
2. Untreated Water to Evaporation Ponds.
3. Seepage Water Diverted to Jordan River.
4. Excess Mine Water Diverted into Bingham Pit.
5. Untreated Water to Evaporation Ponds Stopped.
6. Excess Mine Water Diversion to Bingham Pit Stopped.
7. Seepage Water Diversion to Jordan River Stopped.
CAPACITY (ACRE-FEET)
1000.
900.
800.
700.
600.
500.
400.
300.
200.
100.
0.
1
2 3
4
5
67
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
10/1/83 TO 6/30/84

Figure 10



EXCESS MINE WATER TO
EVAPORATION PONDS
LEGEND
UNTREATED
TREATED
WATER (ACRE-FT)
7200.
6600.
6000.
5400.
4800.
4200.
3600.
3000.
2400.
1800.
1200.
600.
0.
73
74
75
76
77
78
79
80
81
82
83
84
WATER YEAR ENDING JUNE 30, 19XX

Figure 11


CUMULATIVE WATER DIVERSION
TO EVAPORATION PONDS
LEGEND
TREATED
UNTREATED
WATER (ACRE-FEET)
4000.
3600.
3200.
2800.
2400.
2000.
1600.
1200.
800.
400.
0.
OCT
NOV
DEC
JAN
FEB
MAR
APR
MAY
JUN
10/1/83 TO 6/30/84

Appendix I

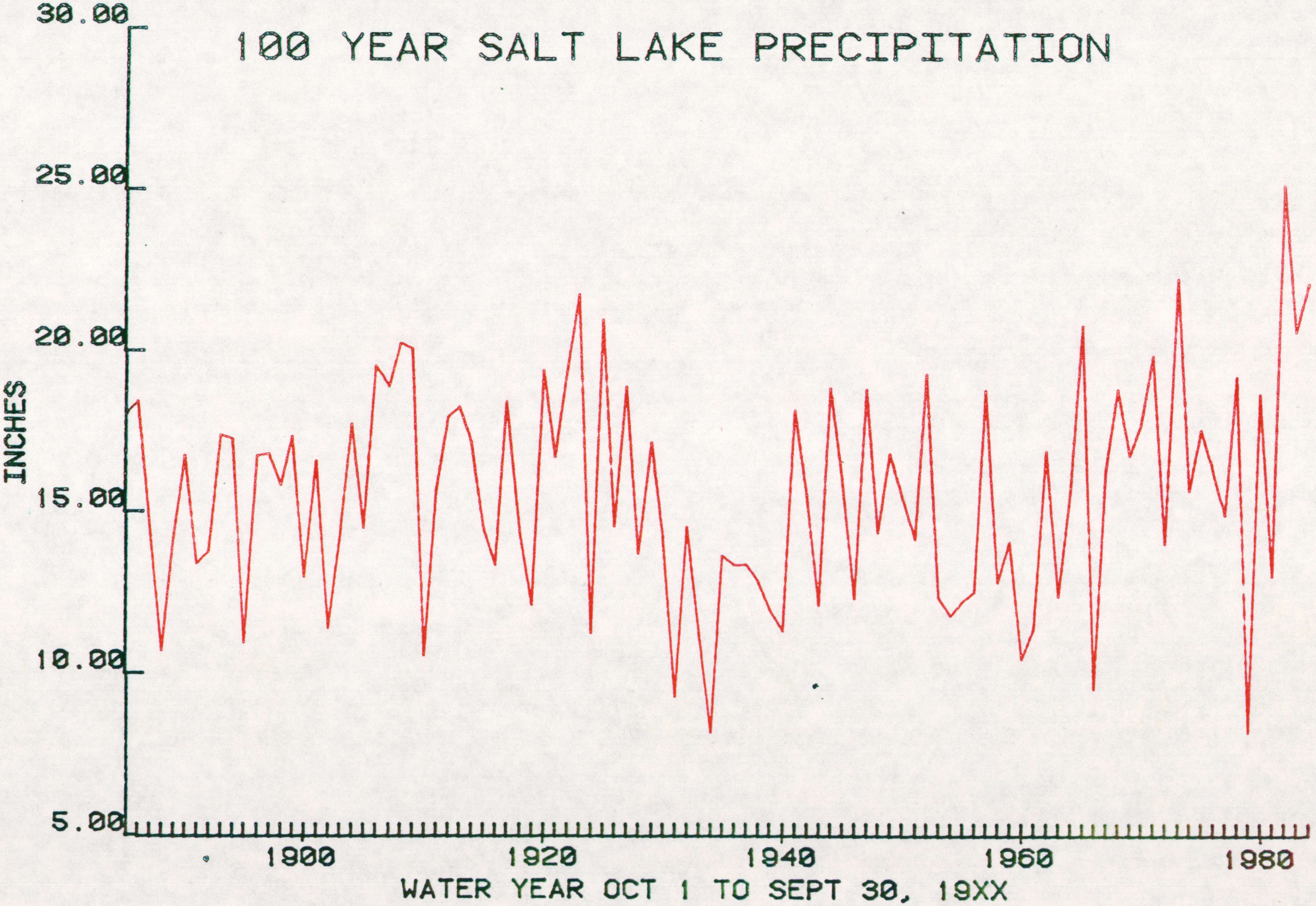
Meteorology and Climatic Change

The Salt Lake area resides in the Great Basin physiographic region, and is located in northern Utah on the western slope of the Wasatch Mountains. The elevation of the Salt Lake Valley ranges from approximately 4,210 feet along the shores of the Great Salt Lake to nearly 12,000 feet in the highest peaks of the Wasatch Mountains. The climate is semiarid, with four well defined seasons. Summers are characterized by hot, dry weather, with spring typically the wettest season. The average annual rainfall at the Salt Lake City airport is 15.31 inches.

During the three-year period ending August 1984, a marked shift to wetter weather occurred, with the average rainfall for this three-year period running 68% above normal at the Salt Lake City airport. The October 1-September 30 water year ending September 30, 1982 was the wettest in 110 years, with the subsequent water year ending September 30, 1983 the fourth wettest on record. The current water year is already within .16 inches of being the second wettest on record, with over one month still remaining. Figure 1 shows Salt Lake precipitation over the last 100 years. As a result of this excessive precipitation, the level of the Great Salt Lake has risen to its highest level in 100 years (Figure 2).

The Bingham Canyon watershed has experienced similar record levels of precipitation during the last three years. Figure 3 shows the average precipitation at the six Bingham Canyon meteorological stations during the last 10 years. The three-year period ending June 30, 1984 averaged 72% above normal. The water content in the Bingham Canyon snowpack during the spring of 1983 was the highest during the previous 30-year period, and was 75% above normal. The 30-year record snowpack experienced during the spring of 1983 was exceeded during the spring of 1984. The water content in the Bingham Canyon snowpack for the spring of 1984 (Table 1) was nearly 90% above the 30-year normal. The combination of record spring snowpack and the wet weather pattern during the 1981-1984 period resulted in the record snowmelt conditions during the 1983 and 1984 spring snowmelt seasons.

Figure 1



NOTE: 1984 DATA IS THROUGH AUG 28, 1984

Figure 2

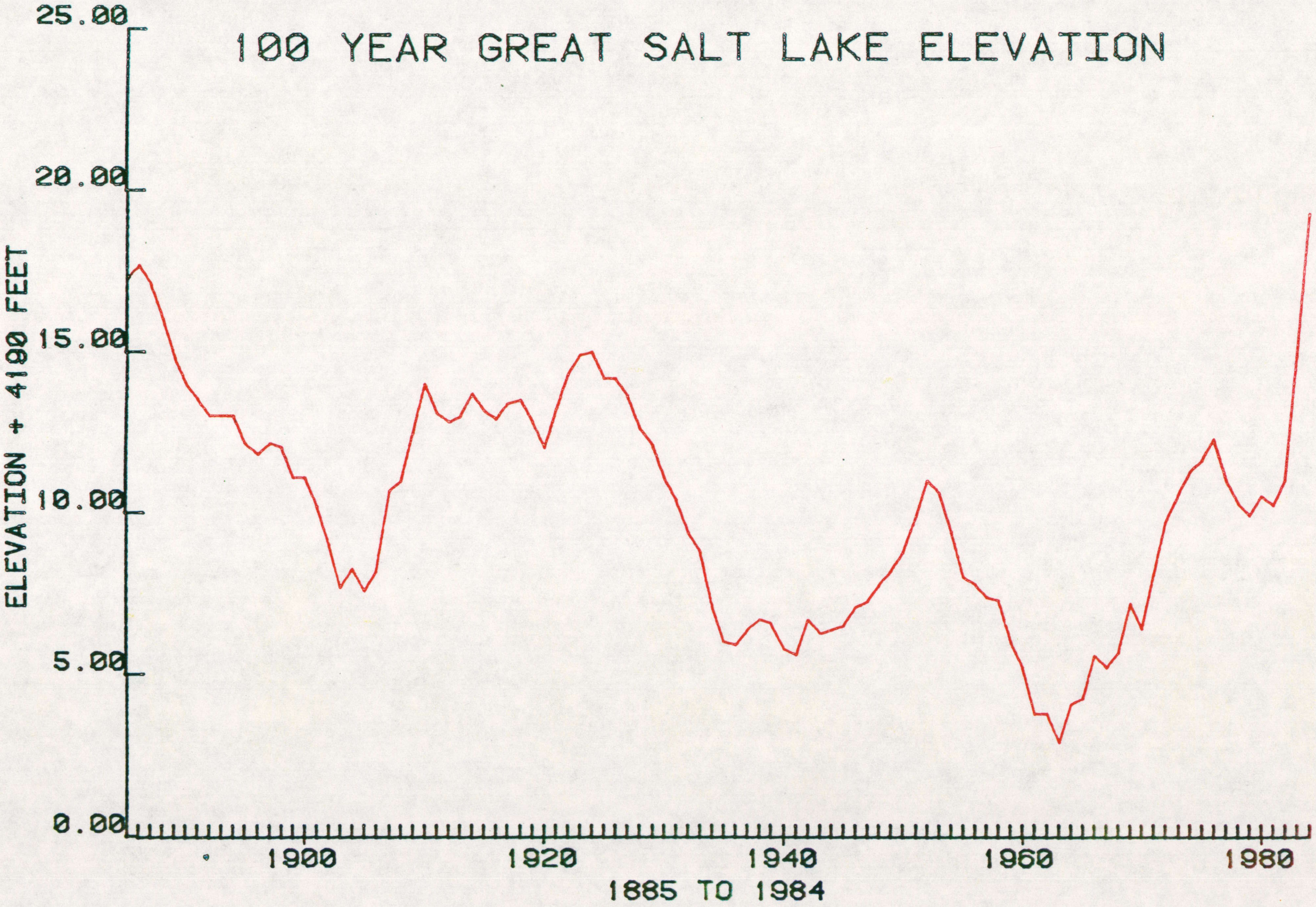
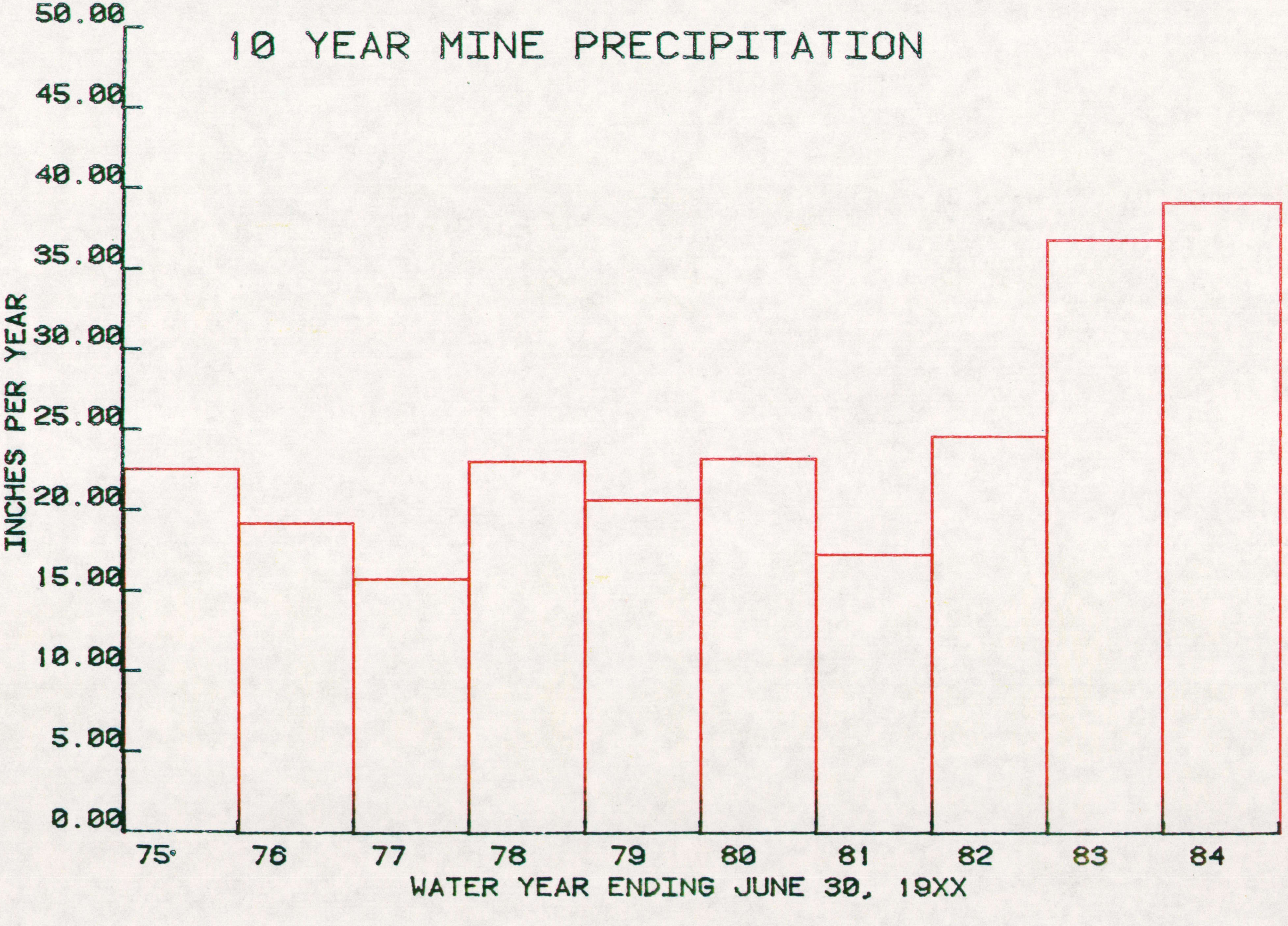

100 YEAR GREAT SALT LAKE ELEVATION
ELEVATION + 4190 FEET
25.00
20.00
15.00
10.00
5.00
0.00
1900
1920
1940
1960
1980
1885 TO 1984

Figure 3



10 YEAR MINE PRECIPITATION
INCHES PER YEAR
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
75
76
77
78
79
80
81
82
83
84
WATER YEAR ENDING JUNE 30, 19XX

Appendix II

Treatment and Water Quality Data

The pH of the drainage from the Bingham Canyon ranges from 3 to 4.5 and the total dissolved solids range from 40,000 to 70,000 mg/l with the primary constituants being iron, aluminum and magnesium sulfates.

Large-scale treatment of the highly mineralized water can be achieved by lime treatment and settling of the precipitated sludge to neutralize the acid and remove dissolved metals. Treatment produces a relatively good quality of water except for the residual calcium sulfate which remains dissolved in the water. Table 1 shows the water quality before and after treatment under optimum treatment conditions. The sludge produced in treatment is an inert material composed primarily of iron, aluminum, magnesium and calcium sulfates. Table 2 shows the sludge composition of heavy metals and the toxicity as characterized by the EP Toxicity Test.

Weekly monitoring of water treatment was conducted through the period October 1, 1983 to June 30, 1984.

Table 3 shows the quality of storm water prior to contacting the ore body.

Table 4 shows the water quality of excess mine runoff prior to treatment.

Table 5 shows the water quality of the treated runoff or combined treated and untreated runoff being routed to the evaporation ponds.

Table 6 shows the quality of water being accumulated in the old evaporation ponds.

Table 7 shows the quality of seepage water being collected on the east side of the delta below the old evaporation ponds.

Table 8 shows the quality of seepage water being collected on the south side of the delta below the old evaporation ponds.

Table 9 shows the quality of seepage water pumped to the Jordan River.

The locations of the private wells adjacent to the evaporation ponds are shown on the map (Figure 1) in the main text of this report. Tables 10 through 14 show the water quality in these wells through July 1984.

The quality of treated water and subsequent collected seepage remained relatively good until the rate of runoff exceeded the treatment capacity, after which only partial treatment of the combined stream was achieved. The relatively poor quality of seepage water collected in the east side system in October and November 1983 reflects the impact of untreated water discharged to the old evaporation ponds during the 1983 spring runoff.

Table 1

Treatment Efficiency

Bingham Canyon Drainage

	Before Treatment (mg/l)	After Treatment (mg/l)
pH	4.5	8.4
TDS	58,400	4,894
Cu	55.8	.06
Zn	108.3	.03
As	<.1	<.004
Pb	.87	.23
Se	<.1	<.004
Ni	17.6	.15

Table 2

Mine Water Treatment

Sludge Composition

EP toxicity test of sludge generated from the treatment of excess mine water using lime neutralization and flocculation.

(Milligrams per Liter)

	EP Concentration	Standard	Total Sludge Concentration
Arsenic	0.09	5.0	0.23
Barium	<0.1	100.0	0.9
Cadmium	0.10	1.0	0.15
Chromium	0.14	5.0	0.17
Lead	0.34	5.0	0.84
Mercury	0.001	0.2	0.001
Selenium	<0.004	1.0	<0.004
Silver	0.02	5.0	0.07

Table 3

Noncontact Precipitation Runoff

Bingham Canyon Watershed

June 25, 1984

Location	pH	Cond	TDS	TSS	Cr	Cd	Cu	Fe	Hg	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
Dry Fork	6.4	325	308	7.2	.06	L .01	.01	.18	L .0001	.3	.02	29.0	L .004	L .01	L .004	L .01	45
Freeman	6.6	50	90	2.8	.01	L .01	.01	.06	L .0001	.4	.01	4.0	L .004	L .01	L .004	L .01	23
Markham	6.5	100	134	1.2	.10	L .01	.01	.20	L .0001	.5	L .01	9.8	L .004	L .01	L .004	L .01	31
Highlandboy	6.5	50	77	51.6	.10	L .01	.01	2.76	L .0001	3.2	.12	3.4	.010	L .01	L .004	L .01	26
Sap Gulch	7.2	100	12	12.0	.13	L .01	.02	.78	L .0001	.5	.03	3.2	.038	L .01	L .004	.01	26

Note: L = Less Than

Table 4

Untreated Mine Water - VW S-353

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
10/26	4.2		12,963				14.88	1400	105	2020	184	3200	.1	.91	.1	21.6	
11/3	4.3		53,950				14.03	1400	104	1910	184	3100	.1	.69	.1	23.6	
11/8	4.2		43,350				16.08	1100	95	1710	163	2800	.1	.66	.1	19.8	
11/10	4.0		57,450				22.00	1400	112	2250	216	3800	L .1	.92	L .1	25.7	
11/14	4.0		66,300				32.00	1700	119	2440	241	4200	L .1	1.06	L .1	29.1	
11/16	4.0		70,950				32.00	1700	120	2480	241	4300	L .1	1.04	L .1	30.5	
11/22							41.00	1385	131	3400	235	4700	L .1	.78	L .1	25.0	
11/23							43.00	1054	106	2090	197	3600	L .1	.69	L .1	20.5	
11/28	5.0						140.00	939	123	3500	219	5200	L .1	1.14	L .1	21.9	
11/30	4.0						86.00	1101	120	3400	219	5600	L .1	1.04	L .1	24.8	
12/2	5.0		72,400				131.00	1041	148	2480	224	4700	L .1	1.25	L .1	24.1	
12/5	5.0		64,300				76.80	1069	119	2250	196	4100	L .1	1.00	L .1	20.5	
12/7	5.0		65,900				77.20	1009	127	2230	206	4300	L .1	.98	L .1	22.0	
12/14	3.9	10,250		L 3	L 3		60.00	911	132	2019	170	4400	L .1	1.00	L .1	19.6	
12/21	4.1		31,005	L 3	L 3	.01	9.24	411	55	980	74	1600	L .1	.51	L .1	8.3	
(1984)																	
1/4				L 3	L 3	.01	77.9	850	118	1400	190	2600	L .1	.75	L .004	16.7	20,073
1/18	4.0	15,000	73,000	L 3	L 3	.02	39.0	1560	141	1965	280	5550	.85	.89	.31	29.8	38,258
1/25	4.0	17,000	24,100	L 3	L 3	.02	30.2	619	60	880	145	3250	L .004	.47	.025	12.7	17,543
2/1	3.9	14,500	63,000	L 3	L 3	L .01	54.3	1700	144	2030	275	5850	L 1	.90	.025	30.3	38,436
2/15			88,200			.08	26.9	21	150	3500	290	6450	L 1	2.35	.008	31.1	45,351
2/22	4.4	11,250	55,032			L .01	12.0	1050	112	1660	17	44	L .004	1.59	.004	18.4	695
3/28							12.8	1150	117	1300	150	3380	.086	1.54	.063	14.0	
4/4	4.0		62,400				13.4	1300	107	1910	200	4100	.90	.76	.015	21.8	32,300
4/18	4.0		42,633	L 3	L 3	L .01	13.5	1100	101	1550	155	3200	.25	.60	L .004	17.0	28,500
4/25	4.1	13,500					52.2	1030	108	1710	165	3500	.30	.64	.200	19.0	29,500
5/2	3.9	11,200	34,399	L 3	L 3	L .01	42.0	930	84	1370	90	1950	.42	.94	.26	16.6	20,900
5/9	3.5	16,280	45,341			L .01	96.9	870	90	1250	127	2900	.71	1.21	.17	21.0	29,600
5/16	3.6	17,000	50,191	L 3	L 3	L .01	75.0	900	98	1410	141	3100	.40	1.22	.19	22.8	35,100
5/23	3.1	19,500	51,727			.01	85.0	870	96	1520	149	3400	.14	1.20	.17	24.1	33,800
5/31	3.3	15,200	37,567			.01	94.7	630	79	1030	93	2100	.046	1.02	.032	16.5	24,300
6/6	3.2	15,250	38,014	L 3	L 3	.01	100.0	432	61	760	92	2800	.017	1.10	L .004	12.8	26,100
6/13	3.6	18,000	45,827			L .01	84.0	458	63	870	93	3300	.100	.96	L .004	3.5	28,500
6/20	3.2	17,500	43,410			.01	44.0	420	61	820	85	2600	.24	1.09	L .004	1.5	34,900
6/27	3.5	12,000	34,934			L .01	25.0	352	52	710	68	2600	.24	.91	L .004	12.0	32,200

Note: L = Less Than

Table 5

Treated Combined Stream - VW S-354

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
10/26	9.7	2,100	5,663				4.91	140.0	.02	180	18.6	390	.004	120	.004	2.21	
11/3	11.4	2,510	4,125				.03	.10	.02	.1	.06	5.0	.004	.18	.004	.10	
11/16	8.5						.05	.16	.02	1.4	2.10	1300	L .004	.28	L .004	.14	
11/30	8.3						.11	.19	.07	1.6	1.74	670	L .004	.17	L .004	.10	
12/28	13.2						.05	.33	.01	.3	.04	L 1	L .004	.29	L .004	.24	
(1984)																	
1/6	7.5			L 3	L 3	.01	.11	.60	.05	.5	9.50	2100	L .004	.35	L .004	.17	8,983
1/11	7.7			L 3	L 3	.02	.07	.58	.02	.7	2.03	800	L .004	.22	L .004	.08	4,693
1/18	7.8	7,500				L .01	.08	1.42	.20	.9	12.40	2500	L .004	.32	L .004	.14	11,033
2/1	6.1	10,000	20,400	L 3	L 3	L .01	.66	395	20.0	1.3	130	3440	L .004	1.05	L .004	6.75	13,474
2/8	7.2	7,000	14,200			.01	.08	.32	.15	.8	7.0	2490	L .004	.79	L .004	.10	9,830
3/7	6.1	5,100					.04	.28	.14	.5	3.24	1291	L .004	.57	L .004	.07	6,455
3/21	8.6	4,200	7,080			L .01	.01	.18	.15	.6	1.59	856	L .004	.46	L .004	.02	5,024
3/28	8.2	4,000	7,000			L .01	.04	.37	.14	1.0	1.44	675	L .004	.39	L .004	.02	4,768
4/4	8.3	4,960	9,660			L .01	.03	.29	.12	1.8	2.00	1040	.014	.22	L .004	.09	6,353
4/25	6.3	7,000	14,825				.28	41.0	3.19	1.0	60	2100	.010	.30	.006	3.44	10,300
5/2	6.5	7,500	14,601	L 3	L 3	L .01	.09	11.7	.95	.1	51	1500	.008	.54	.022	.65	9,950
5/9	5.2	8,100	14,591			L .01	.13	14.2	1.36	1.0	46	1300	L .004	.60	L .004	1.20	11,100
5/16	3.5	12,500	29,900	L 3	L 3	L .01	106	250	6.44	545	62	2600	.22	.88	.073	13.2	18,700
5/23	6.5	7,750	10,362			L .01	.13	.65	.25	2	13.6	1520	L .004	.41	L .004	.06	5,600
5/31	3.9	12,200	25,766			.01	93.5	250	70	530	86	2100	.028	.76	L .004	13.1	17,000
6/6	3.9	14,500	35,829	L 3	L 3	.01	78.0	167	61	730	66	3000	.024	1.04	L .004	13.3	24,500
6/13	4.7	14,500	30,666			.01	59.0	236	58	390	62	2900	.053	.72	L .004	13.1	4,210
6/20	8.6	2,300	2,494			L .01	20.0	10.1	.23	450	.25	3000	L .004	.01	L .004	.60	2,290

Note: L = Less Than

Table 6

Evaporation Pond A - VW S-350

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
11/3	8.5	1475	2075				1.85	4.16	.50	4.0	.74	86	.013	.11	.004	.12	
11/9	8.4	1275	2030	L 3	L 3	L .01	.02	.07	.02		.60		L .004	.06	L .004		
11/16	6.0	1490	2480	L 3	L 3	L .01	.03	.07	.01		.32		L .004	.07	L .004	.02	
11/23	6.5	2900	7675	L 3	L 3	L .01	.06	1.49	.30		8.10		L .004	.14	L .004	.37	
11/30	8.1	2100	4150	L 3	3	L .01	.04	.19	.25		.77		L .004	.11	L .004	.02	
12/7	5.6	1390	1956	L 3	4	L .01	.10	.02	.43	L .1	1.30	99	L .004	.08	L .004	.25	
12/14	6.0	1250	2477	L 3	L 3	.06	.03	.29	.23	L .1	1.68	128	L .004	.11	L .004	.15	
12/21	6.6		4613	L 3	L 3	L .01	.13	.50	1.03	.2	7.80	460	L .004	.13	L .004	.38	
12/28	6.2		6010	L 3	L 3	L .01	.06	.73	.47	.4	25.00	740	L .004	.16	L .004	.43	
(1984)																	
1/4	6.5		3,230	L 3	L 3	.01	.04	.44	.04	.2	4.5	210	L .004	.19	L .004	.15	2,719
5/2	4.3	9,250	25,121	L 3	L 3	L .01	26.2	360	63	310	91	2100	.007	.85	.14	11.1	15,700
5/23	3.9	13,750	39,561				79.5	540	63	1030	132	2450	.004	.12	L .004	19.0	24,900
5/31	4.2	13,000	30,314				89.8	360	69.9	755	96	2350	.33	.98	.18	15.9	19,900
6/6	4.0	12,750	32,566	L 3	L 3	.01	112.0	255	60.0	530	73	2650	.014	1.00	L .004	13.1	21,000
6/13	4.3	10,700	26,114			L .01	37.0	167	41.0	150	71	3300	L .004	.74	L .004	7.9	18,500
6/20	4.2	10,000	23,992			.01	24.0	313	36.0	130	48	2700	L .004	.70	L .004	5.9	17,300
6/27	4.0	10,000	20,993			.01	19.4	260	26.0	96	50	2300	L .004	.98	L .004	5.0	17,800

Note: L = Less Than

Table 7

East Side Seepage - VW S-351

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
10/25	4.4	7000	17,225				16.57	5.03	41.0	214	81	1680		.66	L .004	5.32	
11/3	5.2	7000	15,250				15.37	4.83	33.6	214	74	1410	.29	.80	L .004	4.08	
11/9	4.4	5500	13,864			L .01	14.75	4.77	35.0		72		.25	.80	L .004		
11/16	4.6	5500	12,800	L 3	L 3	L .01	14.00	3.96	26.3		45		.27	.78	L .004	3.80	
11/23	4.45	4450	11,588	L 3	L 3	L .01	14.20	2.80	22.5		57		.25	.71	L .004	3.68	
11/30	5.25	4750	11,213	L 3	L 3	L .01	14.00	4.83	22.0		56		.18	.70	L .004	3.55	
12/7	5.3	4550	10,432	L 3	L 3	L .01	12.10	4.03	20.6	179	49	1170	.11	.67	L .004	3.13	
12/14	5.0	3950	9,643	L 3	L 3	L .01	10.30	2.36	16.9	156	40	1300	.14	.65	L .004	2.70	
12/21	4.5	4000	9,217	L 3	L 3	L .01	9.92	2.04	22.2	146	40	1280	.27	.62	L .004	2.50	
12/28	4.4		9,660			L .01	8.29	.85	18.0	116	35	1080	.19	.53	L .004	1.83	
(1984)																	
1/4			9,650	L 3	L 3	L .01	10.10	3.01	19.3	100	44	860	L .004	.55	L .004	2.35	6152
1/11	4.5		8,870	L 3	L 3	L .01	9.30	2.71	17.8	100	2.7	940	L .004	.39	L .004	2.03	5671
1/18	4.6	3900	8,495	L 3	L 3	L .01	7.67	1.97	12.6	83		920	L .004	.46	L .004	2.01	4917
1/26	4.4	3000	7,920	L 3	L 3	L .01	1.77	.78	11.3	70	32	895	L .004	.42	L .004	1.77	631
1/31	4.4	4380	7,620	L 3	L 3	L .01	7.03	1.33	11.8	76	32	940	.006	.42	L .004	1.85	5743
2/8	4.4	4400	7,310			L .01	7.04	1.01	10.8	9	30	945	.011	.75	L .004	1.76	5022
2/15			7,875			.02	6.70	1.72	10.5	82	30	916	.020	.77	L .004	1.66	5490
2/22	5.1	2750	7,497			.09	6.03	.91	10.0	78	3	859	L .004	.73	.008	1.55	5042
2/29	4.4	3525	7,041			.01	5.74	1.21	9.0	75	27	830	.015	.66	L .004	1.43	5527
3/7	4.7	3600	6,975			L .01	5.20	1.10	9.4	70	23	804	.005	.83	.008	1.20	4645
3/14	4.8	3300	5,965			L .01	4.30	2.50	7.5	59	18	650	.015	.56	L .004	.92	4171
3/21	4.7	3525	6,470			L .01	4.90	.80	8.5	108	21	1250	L .004	.79	L .004	1.02	4730
3/28	4.1	3500	7,190			L .01	4.76	.74	8.1	70	19	690	.025	.60	.010	.88	4645
4/4	4.7	4050	6,980			.01	4.44	.82	7.3	71	18	710	.004	.40	L .004	1.03	4517
4/18	4.9	4200	7,175	L 3	L 3	L .01	4.11	.82	6.4	75	16	690	.010	.33	L .004	.95	4780
4/25	4.6	4450	6,807	L 3	L 3	L .01	3.72	.24	4.9	60	15	670		.27	.043	.90	4450
5/2	4.5	4780	7,193	L 3	L 3	L .01	4.79	1.51	6.7	55	17	660	.021	.51	.009	1.06	4780
5/9	4.3	3850	6,322			L .01	3.57	.69	7.2	47	14	690	.12	.53	.008	.90	4660
5/16	4.5	3800	6,794	L 3	L 3	L .01	5.48	.55	7.0	57	14	660	.060	.50	.007	1.30	4750
5/23	4.3	5250	6.785			L .01	5.05	1.27	7.7	56		750	.004	.50	L .004	1.25	4940
5/31	4.4	4550	6,580			L .01	4.43	.66	6.6	50	15	690	L .004	.49	L .004	1.10	4780
6/6	4.5	4525	7,328	L 3	L 3	L .01	7.06	1.90	8.5	54	19	860	L .004	.50	L .004	1.57	5420
6/13	4.3	5000	7,226			L .01	6.03	1.42	8.0	42	15	840	L .004	.40	L .004	1.14	5500
6/20	4.0	7000	11,160			L .01	12.70	2.41	17.5	84	25	1320	L .004	.49	L .004	4.27	7700
6/27	3.8	6500	11,854			.01	14.50	.27	17.0	89	25	1400	L .004	.57	L .004	3.71	7950

Note: L = Less Than

Table 8

South Side Seepage - VW S-352

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
10/26	4.3	3,325	5,150				7.22	.33	8.9	62	16.7	380	L .1	.40	L .1	1.20	
11/3	5.1	3,300	5,325				7.09	.21	9.3	87	17.7	390	.068	.38	L .004	1.04	
11/16	6.0	3,850	8,580			L .01	5.58	.83	15.5		29.9		.027	.24	L .004	2.56	
11/23	4.7	2,600	5,088			L .01	6.36	.11	7.71		17.0		.29	.22	L .004	1.36	
11/30	5.2	2,850	5,638			L .01	5.97	.29	7.95		18.9		.030	.30	L .004	1.31	
12/7	5.0	4,410	4,807			L .01	3.62	.06	5.56	18.3	15.0	450	L .004	.24	L .004	.88	
12/14	4.4	4,900	4,718	L 3	L 3	L .01	2.72	.10	3.42	13.8	11.8	490	L .004	.26	L .004	.65	
12/28	5.0		5,760	L 3	L 3	L .01	2.03	.47	4.00	12.4	10.4	590	L .004	.21	L .004	.53	
(1984)																	
1/4	5.1		5,880	L 3	L 3	L .01	2.15	.33	2.91	9.0	16.1	720	L .004	.27	L .004	.59	3,464
1/11	5.2			L 3	L 3	L .01	1.88	.66	2.80	7.3	.7	660	L .004	.11	L .004	.58	3,232
1/18	5.3	2,675	5,432	L 3	L 3	L .01	1.56	.15	2.89	3.2	14.1	590	L .004	.17	L .004	.64	3,092
1/25	5.7	2,900	5,250	L 3	L 3	L .01	1.50	.02	3.06	3.0	13.0	640	L .004	.14	L .004		3,000
1/31	6.1	3,300	5,420	L 3	L 3	.04	1.42	.02	3.16	2.0	13.1		.027	.14	L .004	.67	3,773
2/8	5.7	3,500	5,400			L .01	1.62	.19	3.19	2.4	14.0	701	.007	.39	L .004	.61	3,635
2/15			5,515			L .01	1.47	.05	2.88	2.0	12.7	665	.007	.36	L .004	.55	3,291
2/22	5.4	2,800	5,509			L .01	1.40	.11	2.33	3.3	11.2	631	.008	.39	L .004	.45	3,682
2/29	4.9	2,725	5,184			L .01	1.38	.12	2.37	3.5	10.0	626	.058	.34	L .004	.40	4,201
3/7	5.5	3,000	5,372			L .01	1.32	.49	2.45	4.1	9.1	598	.011	.49	.006	.44	3,558
3/14	5.8	1,800	5,336			L .01	1.24	2.59	2.54	4.8	9.6	500	.014	.44	L .004	.44	3,639
3/21	6.2	2,900	5,010			L .01	.24	1.09	1.78	1.3	8.5	549	L .004	.40	L .004	.32	3,366
3/28	6.0	3,100	5,660			L .01	.68	.19	1.78	1.6	10.0	550	.020	.44	L .004	.42	3,684
4/4	6.2	3,250	5,800			L .01	.56	.35	1.78	2.5	11.0	580	L .004	.16	L .004	.50	3,648
4/18	6.4	3,450	5,528	L 3	L 3	L .01	.06	.26	.92	.4	7.0	550	.005	.08	L .004	.33	3,480
4/25	5.2	4,400	8,834	L 3	L 3	L .01	.30		1.10	3.6	20.0	990	.640	.15	.014	.87	5,910
5/2	6.2	3,310	5,782	L 3	L 3	L .01	.51	.30	1.68	2.2	7.2	520	.011	.30	.006	.31	3,850
5/9	5.9	3,200	5,046			L .01	.31	.36	1.33	1.3	6.7	520	.120	.27	.006	.29	3,360
5/16	5.3	4,175	7,182	L 3	L 3	L .01	.46	.61	2.31	1.3	13.8	745	.036	.30	.008	.74	5,250
5/23	6.6	5,250	7,569			L .01	.42	.93	2.91	1.4	15.8	3200	L .004	.35	L .004	.81	5,560
5/31	6.1	7,250	12,166			L .01	2.66	.45	14.5	5.2	45.0	1300	L .004	.47	L .004	3.66	8,660
6/6	5.7	7,000	13,029	L 3	L 3	L .01	5.05	.33	16.0	6.2	35.0	1600	L .004	.50	L .004	3.54	10,300
6/13	4.8	10,250	18,186			L .01	23.0	13.3	38.0	45.0	80.0	1900	.006	.62	L .004	5.70	12,100
6/20	4.7	10,000	17,960			.01	18.8	13.9	34.0	42.0	60.0	1600	L .004	.55	L .004	6.70	13,200
6/27	4.5	8,500	17,597			.02	18.5	3.3	28.0	42.0	69.0	2400	L .004	.78	L .004	6.60	13,700

Note: L = Less Than

Table 9

001 Discharge To Jordan River

Date (1984)	pH	TSS	TDS	MPN-F	MPN-T	O&G	Cu	Fe	Zn	Al	Hg	Mg	As	Pb	Se	Cd	SO_4
5/8	6.4	29.0	4,943	L 3	L 3	L 1	.24		1.79		L .0001		.013	.28		.03	
5/16	6.5	16.0	6,223	L 3	L 3	L 1	.24		1.69		L .0001		.100	.27			
5/23	6.7	10.0	7,313	L 3	L 3	L 1	.25		3.16		L .0001		.004	.41			
5/29	6.4		11,207	L 3	L 3	L 1	.94		14.10		L .0001		.004	.48			
6/5	5.9	47.2	12,543	L 3	L 3	L 1	3.93		16.00		L .0001		.004	.51		.13	
6/13	4.9	39.2	17,946	L 3	L 3	L 1	19.00		40.00		.0001		.004	.65		.22	
6/20	4.5	27.6	17,887	L 3	L 3	L 1	15.60		36.00		.0002		.005	.73		.21	
6/24	4.7	68.8	17,456	L 3	L 3	L 1	11.20		30.00		.0001		.004	.01		.17	

Note: L = Less Than

Table 10

Bateman Private Well - W309

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
11/2	7.1	1250	1136	L 2	L 2	L .01	.05	L .01	.07	L .1	L .01	44	L .004	.01	L .004	.02	246
12/28	7.2		1220				.11	.61	.63	.6	.03	42	L .004	.03		.04	203
(1984)																	
1/24	7.1	1300	1010	L 2	L 2	L .01	.19	.02	.49	.2	L .01	52.5	L .004	.03	L .004	.13	
3/15	7.0	1175	1217	L 2	L 2	L .01	.09	.04	.52	L .1	L .01	54.8	L .004	.03	L .004	L .01	250
5/22	6.9	1350	956	L 2	L 2	L .01	.04	.15	.24	L .1	.02	51.0	L .004	L .01	L .004	.04	233
6/16	6.8	1350	1102	L 2	L 2	L .01	.07	.12	.47		.02	45.0	L .004	L .01	L .004	.02	219

Note: L = Less Than

Table 11

Bowles Private Well - W310

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
11/2	6.9	1190	1583			L .01	.10	L .01	.80	L .1	L .01	77	L .004	.02	L .004	.03	545
12/28	7.0		1700	L 2	L 2	L .01	.10	.64	1.60	.3	.01	80	L .004	.04	L .004	.05	432
(1984)																	
1/24	6.8	1650	1460	L 2	L 2	L .01	.12	.08	.65	.3	L .01	84.5	L .004	.04	L .004	.13	
3/15	6.8	1550	1550	L 2	L 2	L .01	.09	.05	.80	L .01	L .01	92.1	L .004	L .01	L .004	L .01	599
4/5	6.7	1550	1750	L 2	L 2	L .01	.05	.05	1.16	1.00	.10	89.0	L .004	.02	L .004	.05	536
5/22	6.8	1600	1406	L 2	L 2	L .01	.02	.27	.25	L .1	L .01	84.0	L .004	L .01	L .004	.02	536
6/14	6.7	1700	1478	L 2	L 2	L .01	.11	.28	1.38		.02	71.0	L .004	L .01	L .004	.03	533
7/26	6.8	1500	1498			L .01	.03	.10	.34	L .1	.01	85.0	L .004	L .01	L .004	.03	

Note: L = Less Than

Table 12

Schowten Private Well - #311

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
11/4	6.7	1650	1575			L .01	.07	.01	.26	L .1	L .01	85	L .004	.06	L .004	.01	577
12/28	6.8		1780				.06	L .01	.27	.4	.01	82	L .004	.03	L .004	.05	461
(1984)																	
1/24	6.8	1575	1550	L 2	L 2	L .01	.08	L .01	.28	.1	.01	92.5	L .004	.01	L .004	.03	
3/15	6.9	1450	1755	L 2	L 2	L .01	.10	.06	.42	L .1	L .01	102.0	L .004	L .01	L .004	L .01	533
4/4	6.7	1550	1900	L 2	L 2	L .01	.06	.05	.23	.1	.03	106.0	L .004	.01	L .004	.04	629
5/22	6.8	1350	1583	L 2	L 2	L .01	.02	.36	.05	L .1	.01	99.0	L .004	L .01	L .004	.03	726
6/14	6.7	1900	1632	L 2	L 2	L .01	.05	1.19	.48		.02	78.0	L .004	L .01	L .004	.01	644
7/27	6.7	1700	1647			L .01	.02	.31	.22	L .1	.02	95.0	L .004	L .01	L .004	.01	

Note: L = Less Than

Table 13

Tidwell Private Well - #312

Date (1983)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
11/2	6.9	1500	1423	L 2	L 2	L .01	.05	L .01	.04	L .1	L .01	70	L .004	.01	L .004	.02	478
12/28	7.0		1680				.06	.01	.27	.4	.01	70	L .004	.03	L .004	.05	396
(1984)																	
1/24	7.1	1800	1250	L 2	L 2	L .01	.19	.06	.33	.2	.03	96.5	L .004	.01	L .004	.10	469
3/15	6.8	1425	1529	L 2	L 2	L .01	.20	.08	.24	L .1	L .01	88.0	L .004	L .01	L .004	L .01	491
4/5	6.9	1425	1630	L 2	L 2	L .01	.05	.04	.17	L .1	.03	87.0	L .004	L .01	L .004	.03	478
5/22	6.8	1750	1321	L 2	L 2	L .01	.04	.30	.09	L .1	L .01	80.0	L .004	L .01	L .004	.04	448
6/22	6.8	1700	1349	L 2	L 2	L .01	.08	.69	.20		.02	67.0	L .004	L .01	L .004	L .01	446
7/27	6.8	1850	1390			L .01	.02	.11	.11	L .1	.01	80.0	L .004	L .01	L .004	.01	

Note: L = Less Than

Table 14

Ham Private Well - #337

Date (1984)	pH	Cond	TDS	MPN-F	MPN-T	Phoh	Cu	Fe	Zn	Al	Mn	Mg	As	Pb	Se	Ni	SO_4
3/15	6.85	1425	1514	L 2	L 2	L .01	L .01	.25	.22	.2	L .01	79	L .004	L .01	L .004	L .01	589
4/5	6.85	1500	1570	L 2	L 2	L .01	.02	.19	.19	L .1	.01	75	L .004	L .01	L .004	.02	593
5/22	6.9	1550	1530	L 2	L 2	L .01	.03	.54	.18	L .1	.01	76	L .004	L .01	L .004	.03	596
6/14	6.8	1450	1497	L 2	L 2	L .01	.07	.28	.33		.03	54	L .004	L .01	L .004	.01	593
7/26	6.8	1200	1218			L .01	.01	.26	.27	L .1	L .01	54	L .004	L .01	L .004	.01	

Note: L = Less Than

Table 1

Bingham Canyon

Water Content in Snowpack Versus Elevation

Elevation (feet)	April 1, 1984 (inches)	May 1, 1984 (inches)
6000	19.8**	24.1**
6500	23.4*	26.9*
7000	27.0*	29.7*
7500	31.6**	36.2**
8000	36.2**	42.7**
8500	40.8**	49.2**
9000	45.4*	55.8*

30-year Average - Water Content

1955-1984

Elevation (feet)	April 1 (inches)	May 1 (inches)
6500	11.6	4.9
7000	14.5	9.3
9000	28.0	29.5

*Known Values

**Estimated Values

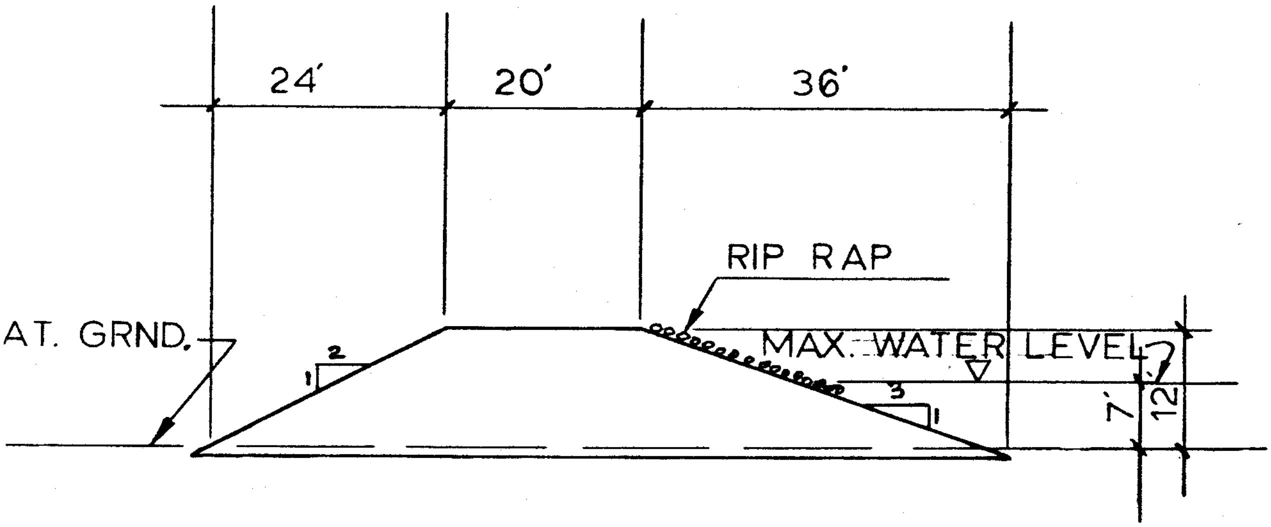
Source: Snow Survey
Soil Conservation Service
U.S. Dept. of Agriculture

Appendix III

Evaporation Pond Design

The location of the evaporation ponds is shown in Figures 1 and 6 of the main text. The pond and dike areas were stripped of topsoil and organic material prior to construction. Scrapers were used to excavate the clay from the borrow areas and spread the material in the dike areas in six-inch lifts. The material was compacted with a compactor and a sheepsfoot roller. Figure 1 shows the dike cross section. The ponds were constructed with a 12-foot nominal depth from the pond bottom to the top of the dike. The spillway or overflow outlets were placed seven feet above the bottom of the pond. The upper seven feet of the inside slopes and the overflow outlets were riprapped with mine waste rock. Table 1 shows the area and capacity of both the old and new evaporation ponds.

Following construction of the new evaporation ponds, a stability evaluation was conducted by Dames & Moore, an independent consultant to Kennecott, to determine the stability of the perimeter embankments. The stability was evaluated under both steady-state seepage and seismic loading conditions. The results of the evaluation show the evaporation ponds conform to the general requirements for standard engineering practice, and the estimated factors of safety are above the minimum recommended requirements. A copy of this evaluation is included in this appendix.



CLAY DIKE - COMPACTED IN 6 INCH LIFTS

EVAPORATION PONDS TYP. DIKE CONSTRUCTION	KENNECOTT
	K.L.R. 9-5-84
	DRAWING NO. / REV.

Table 1

Evaporation Pond Capacity

New ponds constructed in clay base or clay lined:

Pond No.	Maximum Water Depth (feet)		Surface Area (acres)	Capacity (acre-feet)
1	7		2.2	15.4
2	7		4.5	31.5
3	7		9.4	65.8
4	7		24.3	170.1
5	7		39.0	273.0
6	7		68.2	477.4
7	7		33.9	237.3
		Total	182	1271

Old ponds used and unused:

Pond No.	Maximum Water Depth (feet)		Surface Area (acres)	Capacity (acre-feet)
A	7		87.3	611.1
B	5		20.4	102.0
C	5		61.9	309.5
--	5		176.0	880.0
--	5		102.5	512.5
--	5		16.0	80.0
--	5		11.8	59.0
--	5		12.4	62.0
		Total	488	2616

Dames & Moore

250 East Broadway, Suite 200
Salt Lake City, Utah 84111
(801) 521-9255
Cable address: DAMEMORE

September 5, 1984

Kennecott Minerals Company
P. O. Box 31838
Salt Lake City, Utah 84131-0838

Attention: Mr. S. D. Taylor

Gentlemen:

Report
Stability Evaluation
Existing Evaporation Ponds
Bingham Canyon Operations
For Kennecott Minerals Company

INTRODUCTION

This report presents the results of our stability analysis performed for Kennecott's seven existing evaporation ponds located at approximately 4400 West and 11300 South in Salt Lake County. The general location of the ponds is shown with respect to surrounding topography on Plate 1, Vicinity Map. A detailed layout of the pond area showing local topography is presented on Plate 2, Plot Plan.

PURPOSE AND SCOPE

The purpose and scope of this investigation were planned in discussions between Ms. Terry Vandell of the Kennecott Minerals Company and Mr. Larry Murdock of Dames & Moore. In brief, the purpose of this investigation was to evaluate the stability of the perimeter embankment systems for the ponds in question and to provide appropriate geotechnical recommendations as required. In accomplishing this purpose our scope of work included:

1. A field exploration program which consisted of:

    a. A field reconnaissance by an experienced geotechnical engineer.

    b. The drilling, logging and sampling of 15 exploration borings along the embankment system.

    c. The installation of an open standpipe piezometer in each of the exploration borings.

2. A laboratory testing program.

3. An engineering analysis program which included correlating all available data and evaluating the stability of three critical sections within the embankment system.

4. The preparation of this final summary report.

SITE CONDITIONS

SURFACE

The seven ponds are located in the moderately sloping topography to the northwest of Riverton, Utah. The ponds are numbered 1 through 7 as shown on Plate 2 and range in surface area from approximately 1.0 to 80 acres. In general, the perimeter dikes are relatively small with the average height being on the order of 10 to 15 feet. It is our understanding that these dikes have been constructed out of the natural soils excavated from the interior of the individual impoundments. The deepest embankment section occurs in the southeast corner of Pond 5 where the maximum height is approximately 35 feet. Both the downstream and upstream embankments for all of the ponds are constructed at slopes ranging from approximately 2.5 to 2.0 horizontal to 1.0 vertical. The upstream face of each dike has been protected with a 1.0 to 2.0 foot layer of riprap.

At the time of our investigation water was impounded in Ponds 1, 2, 3, 4, and 7. In Pond 5 only a small volume of water had collected within the extreme southeast corner of the impoundment. The maximum depth of water was estimated to be approximately 1.0 foot. In Pond 6 water was impounded only in the extreme eastern and western portions. Pertinent data for each of the seven ponds is presented in tabular form below.

Pond No.	Pond Size in Acres	Crest Elevation in Feet	Maximum Embankment Height in Feet	Present Freeboard in Feet
1	2.2	4751	12	6.0
2	4.5	4752	15 *	6.5
3	9.4	4751	15 *	6.0
4	24.3	4751	15 *	8.5
5	39.0	4734	35	15.0
6	68.2	4809	15	9.0
7	33.9	4768	19 *	8.0

* Maximum height measured from crest of adjacent embankment

SUBSURFACE SOILS

The subsurface conditions at the site were evaluated through the drilling, logging and sampling of 15 exploration borings. A discussion of this program and the subsequent laboratory evaluation is presented in the Appendix to this report.

The results of our investigation indicate that the natural foundation soils and the fill materials utilized in the construction of the embankments are relatively uniform in Ponds 1, 2, 3, 4, 5, and 7. The foundation soils consist of a brown silty clay or clayey silt with a trace of fine-grained sand. These soils graded with interlayered sequences of silty fine to coarse-grained sands and gravels. The cohesive soils were generally classified as stiff to very stiff with the more granular soils classified as medium dense to dense. The embankment fill soils were similar in gradational characteristics and were generally classified as a brown clayey silt with a trace of fine to coarse-grained sand and gravel. The fill appeared to be relatively uniform in consistency and ranged from stiff to very stiff.

In the Pond 6 area the exploration borings indicated substantially different subsurface conditions. The natural soils in this area consisted of a brown fine to coarse-grained gravelly sand with a trace of silt. This soil was classified as medium dense to dense and will exhibit relatively high permeability characteristics. The embankment soils were generally classified as a dark brown clayey fine and coarse gravel with some fine and coarse sand which ranged in consistency from loose to medium dense. Due to the more granular nature of these materials they exhibit higher strength characteristics than those encountered in the adjacent pond areas.

GROUND WATER

At the time of our field investigation water levels were recorded in the exploration borings. Most of the borings were dry to the depth penetrated. However, water was encountered in Borings 4, 5 and 8 which were drilled in the perimeter dikes for Ponds 2 and 3. The recorded water levels are presented to the left of the boring logs in the Appendix of this report.

In order to provide for long-term monitoring, open standpipe piezometers were installed in each of the borings. Details pertaining to the installation are also presented in the Appendix.

SEISMICITY

The geoseismic setting of the general site area has been evaluated by Dames & Moore during a previous geotechnical investigation for the Kennecott Minerals Company. The results of this investigation were presented in a report dated February 4, 1983.*

In brief, the results of this study indicate that the site is situated in a region of relatively high seismicity. For a pseudo-static analysis a seismic horizontal acceleration coefficient of .15g was recommended. This value, with a design earthquake of M = 7.5, was found to have an 88 percent chance of not being exceeded in a 50-year period. This event would have a return period of approximately 420 years.

SLOPE STABILITY

GENERAL

In evaluating the stability of the evaporation pond embankment system an analysis was performed on three specific cross-sections. The locations of these cross-sections are referenced on Plate 2. The analyses evaluated the stability of the existing embankments under presently accepted minimum levels of factors of safety for both steady-state seepage and seismic loading conditions. In the subsequent sections, we present discussions pertaining to the design assumptions utilized in our analyses and final conclusions regarding the embankment's overall stability.

* "Report Evaluation of Future Tailings Disposal, Utah Copper Division (UCD) Tailings Pond, Near Magna, Utah, Kennecott Minerals Company."

EMBANKMENT SECTION ANALYZED

The geometry of the three embankment sections analyzed is presented on Plate 3, Critical Embankment Sections. In general, these sections were considered to be representative of the most critical encountered along the alignment. The sections were developed from preliminary survey data developed during our field investigation program and from the topographical information presented in Plate 2.

The design phreatic lines utilized in our analyses are also presented on Plate 3. This condition is considered to represent the maximum anticipated water levels which could occur within the embankment sections analyzed. In evaluating this maximum design condition, consideration has been given to the maximum operating levels within the individual ponds, the existing piezometric readings and our general experience with similar facilities.

SOIL PARAMETERS

Soil parameters used in our analysis were derived by interpreting laboratory test data, the results of which are presented in the Appendix to this report. The strength characteristics of the natural foundation soils were evaluated through a series of consolidated-undrained triaxial compression tests which were performed on undisturbed samples taken from the borings. These tests provided both total strength (undrained) parameters and effective strength (drained) parameters. The strength properties determined for the natural soils were also utilized to simulate those of the embankment fill materials. This is, in general, considered to be a conservative estimate as the majority of the embankment soils have been compacted to densities well in excess of their natural in situ values.

The strength parameters utilized in our analysis are presented in tabular form on the following page.

Material	Steady-State Seepage Effective Stress (Drained Conditions) Friction Angle Ø', in degrees	Cohesion c', in psf	Seismic Loading Conditions (Undrained Conditions) Friction Angle Ø, in degrees	Cohesion c, in psf	Total Density, in pcf
Compacted Embankment Soils	32	0	20	300	120
Natural Foundation Soils	32	0	20	300	110

METHOD OF ANALYSIS

GENERAL

The stability of the existing and final embankment section was calculated by the Simplified Bishop Method, using a computer and the Dames & Moore Program EP-1. The Dames & Moore Modified Bishop computer analysis for slope stability has received certification under the Dames & Moore Quality Assurance Program which has been audited by many of the large utility companies as well as by regulatory agencies.

The Simplified Bishop technique assumes a circular failure surface with the soil failing as a series of rigid-body segments. The effects of internal deformation within the soil mass are neglected. In considering any given circular surface, the driving and resisting forces associated with the failure are calculated. The factor of safety for any circular surface is essentially the summation of the resisting forces divided by the summation of the driving forces.

The stability of the final embankment sections was evaluated under both steady-state seepage and seismic loading conditions. For steady-state seepage conditions, effective stress strength parameters were used in the analysis. The earthquake (seismic) conditions were analyzed utilizing "total stress" parameters to simulate the strength of the materials under the application of a seismic load. The seismic load is represented by the application of a horizontal force equal to an assumed percent of gravity acceleration applied to the weight of soil within the failure circle. As presented previously, the design earthquake was estimated to have a maximum design acceleration at the site of .15g. The design assumptions utilized are discussed in previous sections of this report and are shown on Plate 3.

RESULTS

The geometry, soil parameters and ground water conditions used in our analysis, along with the resulting stability factors of safety, are shown graphically on Plate 3. Results of our analysis are summarized in tabular form below.

SUMMARY OF SLOPE STABILITY ANALYSIS

	Factor of Safety	
	Steady-State Seepage	Seismic Loading
Section A-A	1.62	1.28
Section B-B	2.43	2.24
Section C-C	1.71	1.45

The minimum factor of safety calculated represents the degree of stability of the slope for each loading condition. The design guidelines for mine waste piles and tailings dams used by the U.S. Mine Safety and Health Administration state that, for the stability of an impounding structure, the minimum factors of safety for static and dynamic conditions are to be 1.5 and 1.2, respectively. All calculated factors of safety for the embankment sections analyzed were found to be greater than these minimum values.

CONCLUSIONS

GENERAL

The results of our investigation indicate that the stability of the present evaporation pond system conforms to the general requirements for standard engineering practice. The estimated factors of safety are above the minimum recommended requirements and thus, the potential for any significant failure to occur within the perimeter embankment system appears to be minimal. Based upon these results, specific remedial measures are not recommended at this time. However, it is recommended that the facility be subjected to a regular program of embankment surveillance throughout its operational period. A brief discussion of this program is presented in the following subsection.

EMBANKMENT SURVEILLANCE

It is recommended that during the entire period of operation, the impoundment areas be subjected to a regular program of embankment surveillance. This program should consist of a weekly inspection by qualified operational personnel. During this weekly inspection, attention should be given to any signs of tension cracking, sloughing, erosion or seepage on the downstream face of the embankments. Appropriate records should be maintained for each inspection. Unusual features noted during the weekly inspections should be immediately reported to a registered geotechnical engineer who may suggest a site visit to confirm and observe the problem area. Immediate remedial measures should be undertaken to repair any distress noted or potential instability. In addition, the installed piezometers should be read and recorded on a monthly basis. In the event that water levels in excess of those utilized in our analyses are encountered, Dames & Moore should be notified immediately.

oOo

We appreciate the opportunity of performing this service for you. If you have any questions or require additional information, please feel free to contact us.

Respectively submitted,

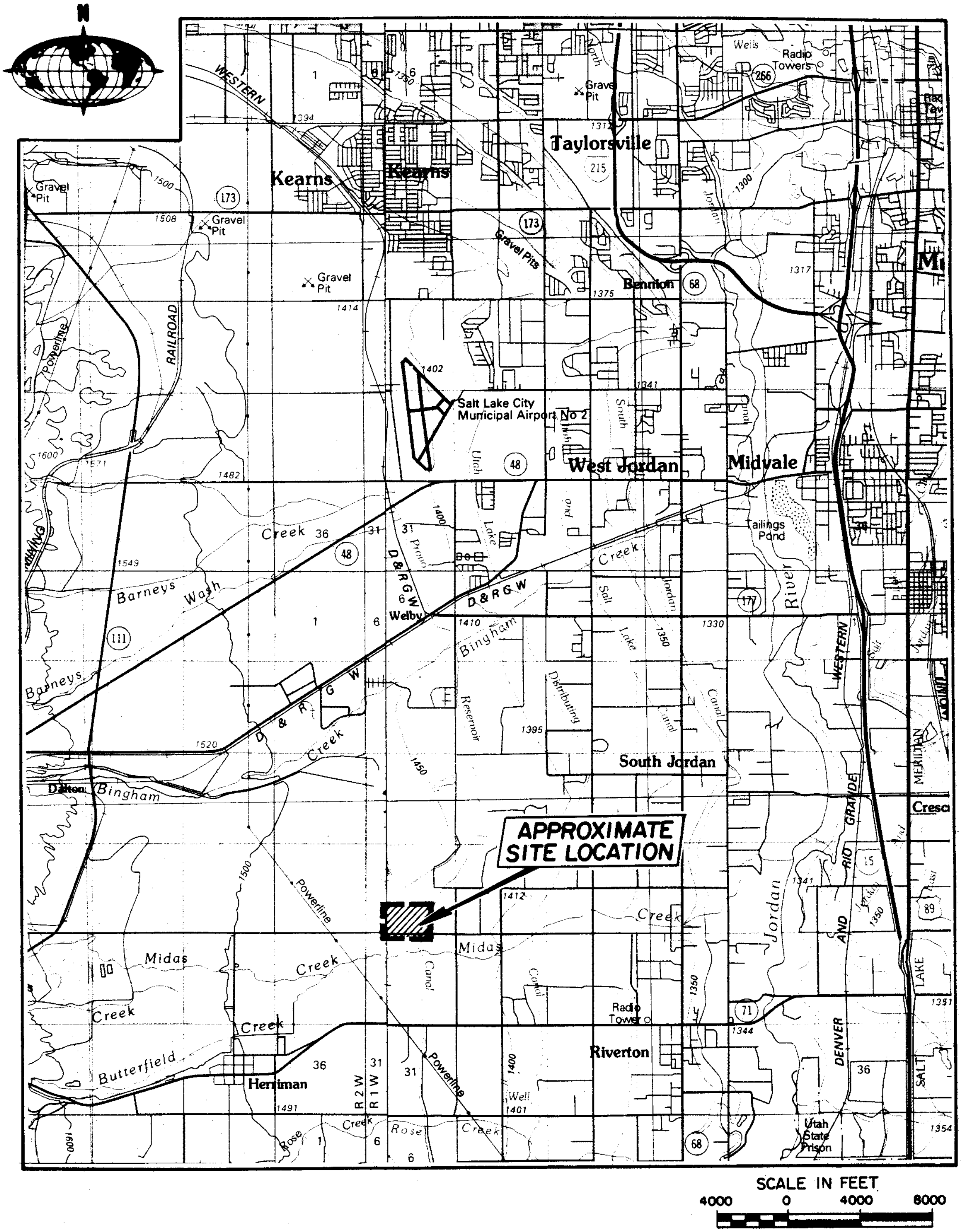
DAMES & MOORE

Larry T. Murdock
Partner
Professional Engineer No. 2987
State of Utah

James F. Zitnik
Senior Engineer

LTM/JFZ:fl

cc: Terry Vandell
Bob Malone



VICINITY MAP

REFERENCES
U.S.G.S. 1:100,000 SCALE METRIC MAPS ENTITLED "SALT LAKE CITY, UTAH - WYOMING" - 1980, AND "TOOELE, UTAH" - 1979.

Dames & Moore

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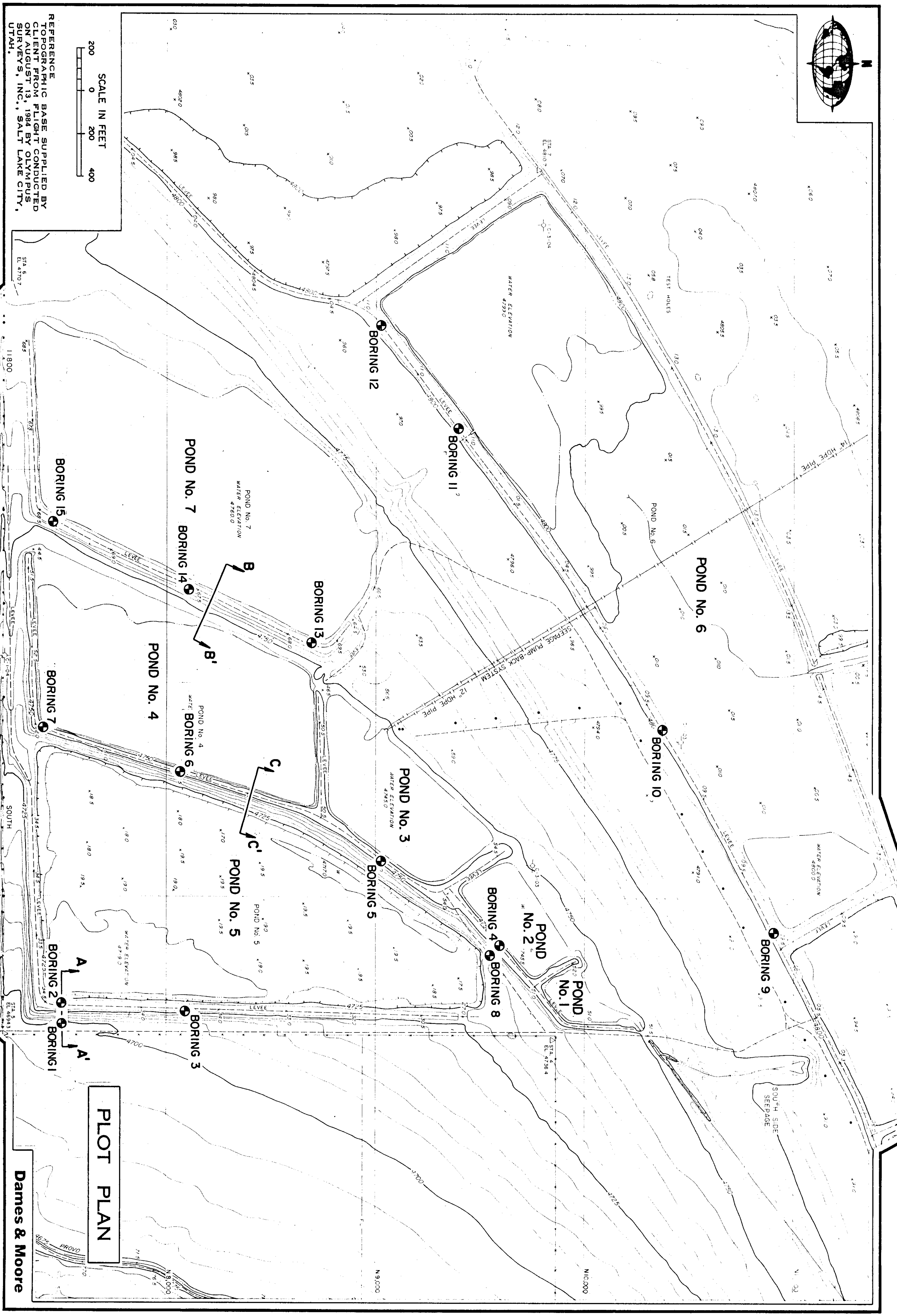

PLATE 2

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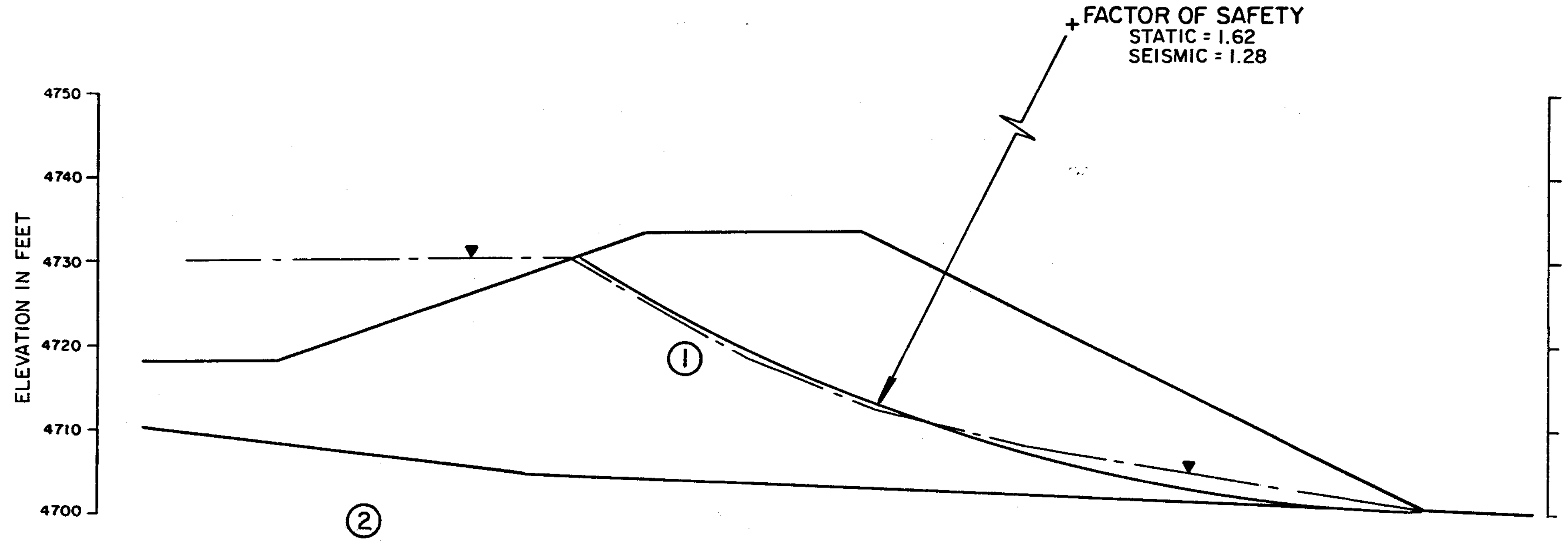
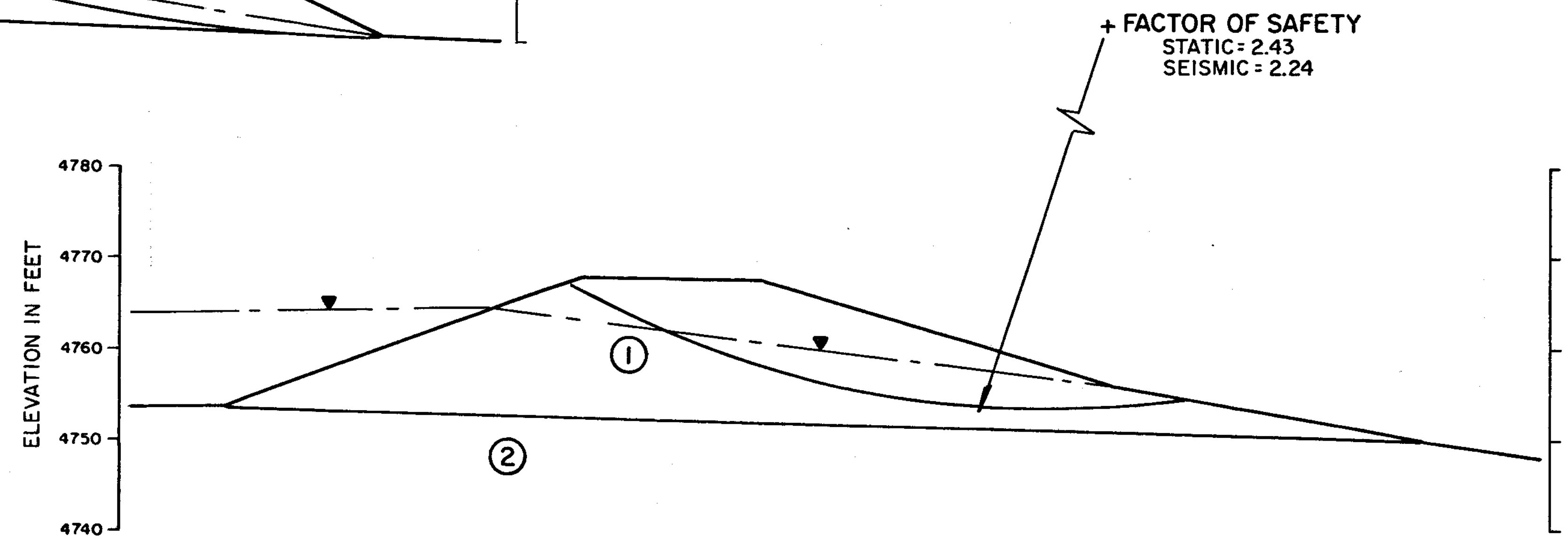
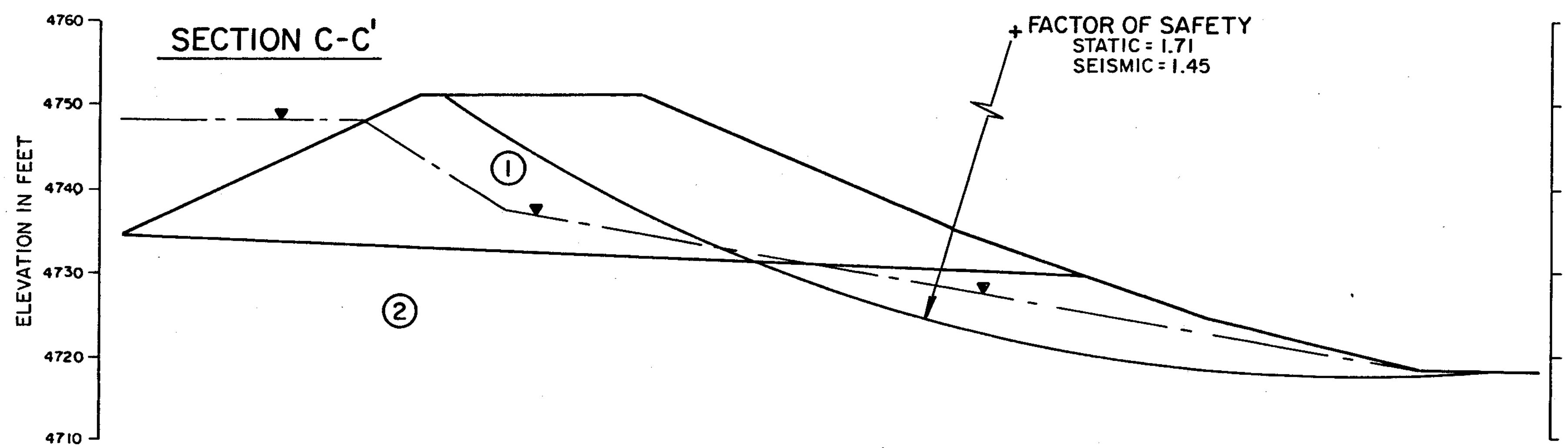
GEOTECHNICAL PARAMETERS						
			STEADY-STATE SEEPAGE — TOTAL STRESS (UNDRAINED CONDITIONS)		SEISMIC LOADING CONDITIONS — EFFECTIVE STRESS (DRAINED CONDITIONS)	
	MATERIAL	γ IN PCF	FRICTION ANGLE, ϕ	COHESION C IN PSF	FRICTION ANGLE, ϕ	COHESION C IN PSF
1	COMPACTED EMBANKMENT SOILS	120	32	0	20	300
2	NATURAL FOUNDATION SOILS	110	32	0	20	300



SECTION A-A'



SECTION B-B'



SECTION C-C'

CRITICAL EMBANKMENT SECTIONS

Dames & Moore

APPENDIX A

FIELD AND LABORATORY INVESTIGATION

FIELD INVESTIGATION

GENERAL

The field exploration program performed for this study consisted of a general site reconnaissance conducted by an experienced Dames & Moore geotechnical engineer, the drilling, logging and sampling of 15 exploration borings and the installation of an open standpipe piezometer at each boring. The locations of the borings are presented on Plate 2 in the main text. The exploration borings were drilled utilizing a truck-mounted rotary drill rig with hollow-stem augers.

The drilling operations were performed under the direct control and supervision of an experienced member of our geotechnical staff. Undisturbed samples of the soils encountered within the borings were obtained using a Dames & Moore Type U split-barrel sampler as shown on Plate A-1, Soil Sampler Type U. Disturbed samples of the soils encountered in the test pits were obtained using hand sampling techniques. A complete log was maintained in the field for each test pit and boring, and the materials were calssified by visual and textural examination. These classifications were later supplemented by subsequent inspection and testing in our laboratory. Detailed graphical representation of the subsurface conditions encountered is presented on Plates A-2A through A-2E, Log of Borings.

SOIL CLASSIFICATION

The Unified Soil Classification System shown on Plate A-3 was used in describing the soil encountered. The densities and consistencies noted on the logs were determined using blow counts per foot of penetration of the Dames & Moore sampler and through examination of the undisturbed samples. The correlations shown on the following page relate in an approximate manner the descriptions to the Dames & Moore Type U sampler blow counts.

COHESIONLESS SOILS

Verbal Description	Dames & Moore Sampler (blows/ft)*
very loose	0 - 10
loose	10 - 26
medium loose	26 - 72
dense	72 - 104

COHESIVE SOILS

Verbal Description	Dames & Moore Sampler (blows/ft)*
very soft	0 - 2
soft	2 - 5
medium stiff	5 - 11
stiff	11 - 22
very stiff	22 - 60
hard	> 60

* Using 140 pound hammer falling 30 inches

PIEZOMETER INSTALLATION

During the course of this investigation piezometers were installed in each of the exploration borings for the purpose of providing present and future data pertaining to the embankment's phreatic condition. The piezometers consisted of one and one-half inch diameter blank Schedule 40 PVC pipe which extended to the depth penetrated by the boring. The bottom 10.0 feet were slotted and the adjacent annular space sand packed. The remaining backfill materials consisted of available drill cuttings.

The water levels have been periodically recorded both during and subsequent to our field investigation program. The latest of these readings is presented to the left of the boring logs on Plates A-2A through A-2E.

LABORATORY TESTING

GENERAL

The purpose of the laboratory testing program was to determine the strength, permeability and index properties of the dam foundation and fill materials. Types of laboratory tests performed included: moisture and density and triaxial compressin tests. An explanation of the individual tests and the results are presented in the following subsections.

MOISTURE AND DENSITY

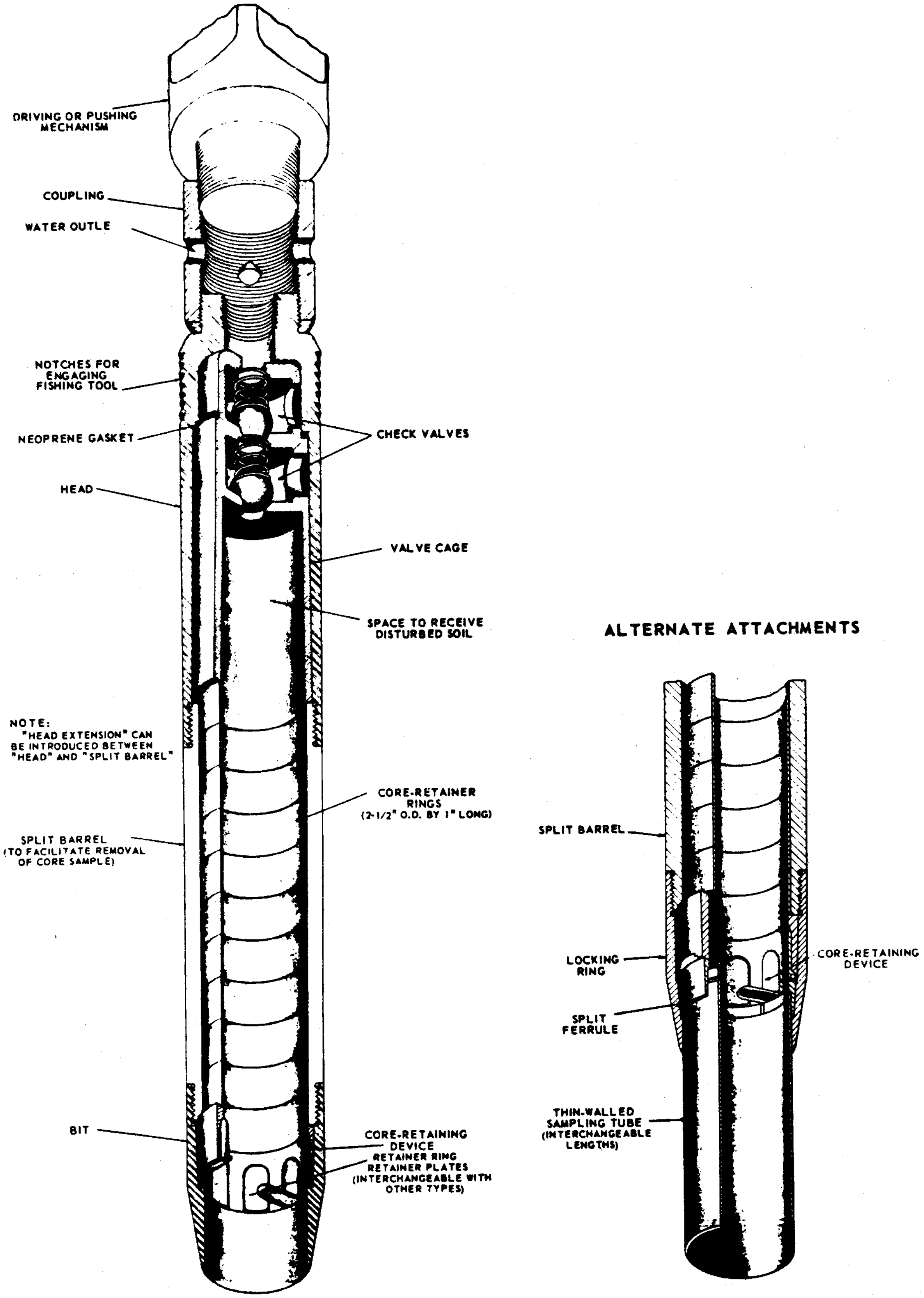
Moisture and density determinations were performed in order to aid in classifying materials and to help correlate test results. The resuts of the moisture and density tests are presented to the left of the boring logs on Plates A-2A and A-2E.

TRIAXIAL COMPRESSION

Consolidated undrained (CU) triaxial compression tests were performed on selected undisturbed samples of the natural foundation soils encountered in the borings. The tests were used to estimate drained and undrained strength parameters.

The tests were performed in general accordance with the procedures presented on Plate A-4, Method of Performing Unconfined Compression and Triaxial Compression Tests. The samples were initially saturated to a B value of at least .95 and then consolidated under a designated confining pressure. The samples were loaded to failure utilizing a deformation rate estimated from data obtained during the consolidation sequence. Pore pressures were measured periodically throughout the duration of the test.

The results of the tests as well as all pertinent data are presented on Plate A-5, Triaxial Compression Test Report.



SOIL SAMPLER TYPE U

U. S. PATENT NO. 2,318,062

DAMES & MOORE

PLATE A-1

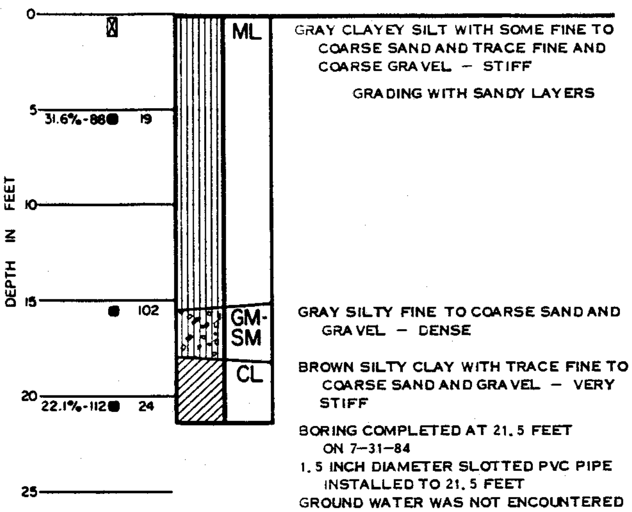
REVISIONS BY ____ DATE ____

FILE ____

CHECKED BY ____ DATE ____

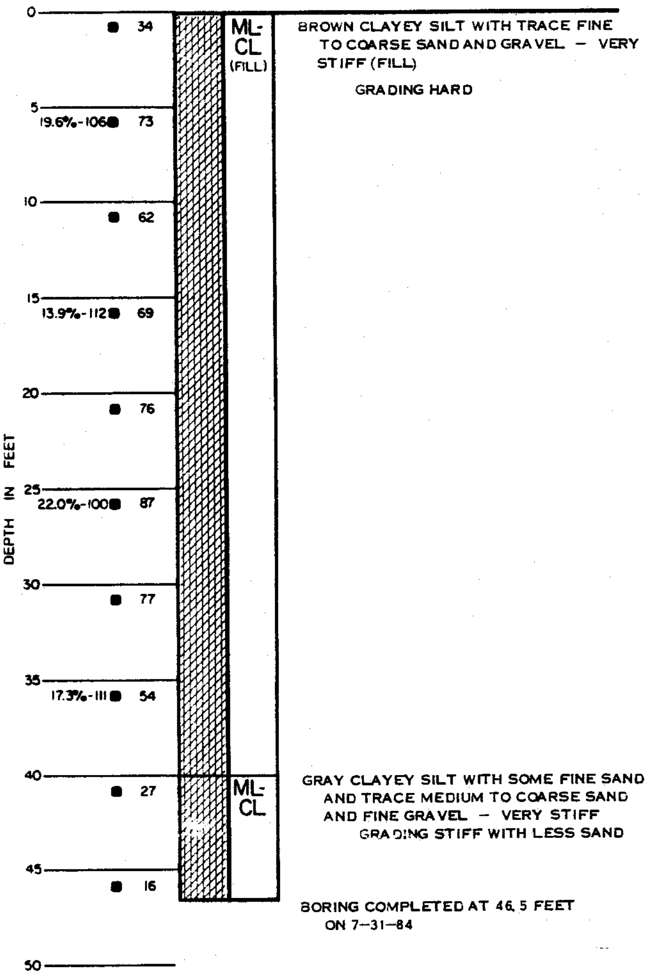
BORING 1

ELEVATION 4700'*



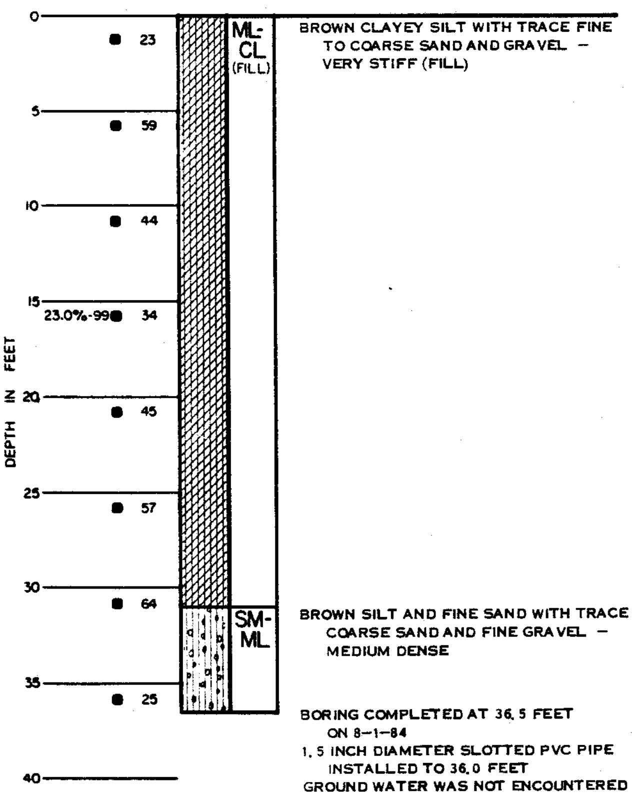
BORING 2

ELEVATION 4734'*



BORING 3

ELEVATION 4734'*



KEY

A – B ■ C

- A FIELD MOISTURE EXPRESSED AS A PERCENTAGE OF THE DRY WEIGHT OF SOIL
- B DRY DENSITY EXPRESSED IN LBS. PER CUBIC FOOT
- C BLOWS REQUIRED TO DRIVE A D&M TYPE U SAMPLER ONE FOOT WITH A 140 LB. HAMMER DROPPING 30 INCHES
- ■ DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED
- ⊠ DEPTH AT WHICH DISTURBED SAMPLE WAS EXTRACTED
- □ SAMPLING ATTEMPT WITH NO RECOVERY
- ⊠ BULK SAMPLE

NOTES

THE DISCUSSION IN THE TEXT UNDER THE SECTION TITLED, "SITE CONDITIONS, SUBSURFACE", IS NECESSARY TO A PROPER UNDERSTANDING OF THE NATURE OF THE SUBSURFACE MATERIALS.

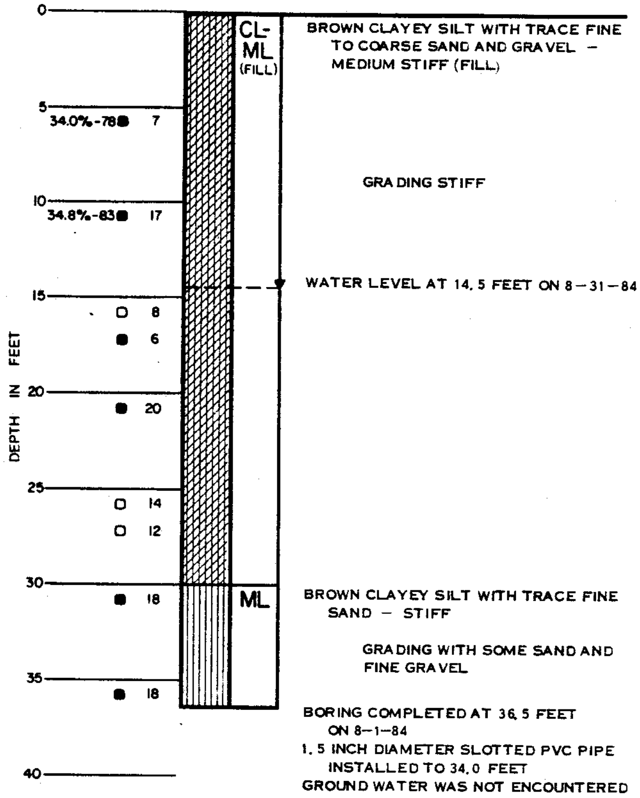
GROUND SURFACE ELEVATIONS AT THE BORING LOCATIONS WERE INTERPOLATED FROM THE TOPOGRAPHIC INFORMATION PRESENTED ON PLATE 2, PLOT PLAN.

LOG OF BORINGS

Dames & Moore

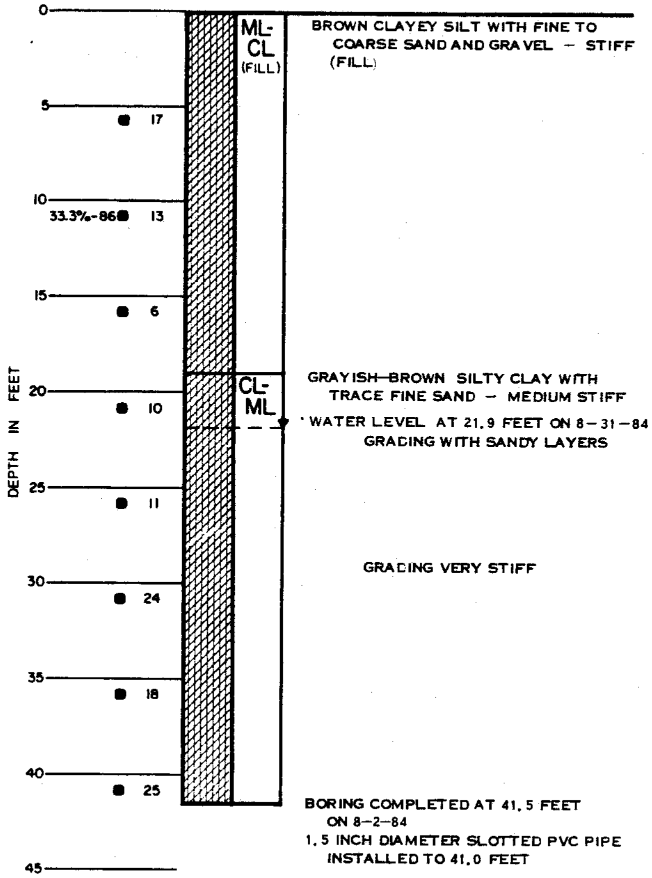
BORING 4

ELEVATION 4752'*



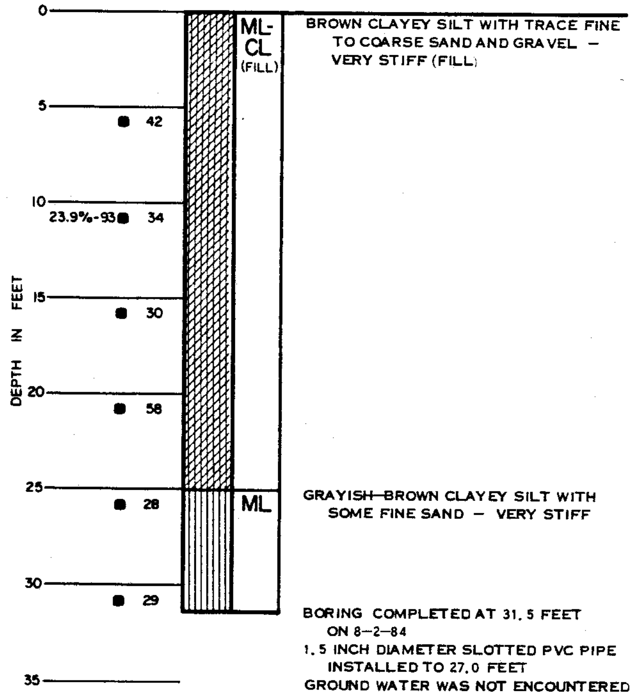
BORING 5

ELEVATION 4751'*



BORING 6

ELEVATION 4751'*



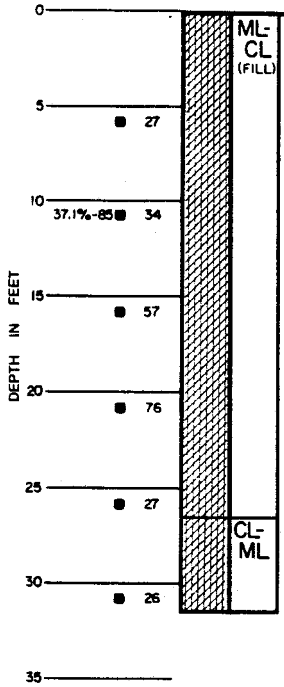
LOG OF BORINGS

Dames & Moore

PLATE A-2B

BORING 7

ELEVATION 4752'*



BROWN CLAYEY SILT WITH TRACE FINE TO COARSE SAND AND GRAVEL – VERY STIFF (FILL)

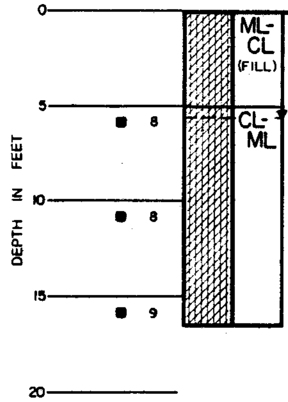
GRAY CLAYEY SILT WITH TRACE FINE SAND – STIFF

GRADING WITH MORE SAND

BORING COMPLETED AT 31.5 FEET ON 8–2–84
1.5 INCH DIAMETER SLOTTED PVC PIPE INSTALLED TO 31.5 FEET
GROUND WATER WAS NOT ENCOUNTERED

BORING 8

ELEVATION 4735'*



BROWN CLAYEY SILT WITH TRACE FINE TO COARSE SAND AND GRAVEL – MEDIUM STIFF (FILL)

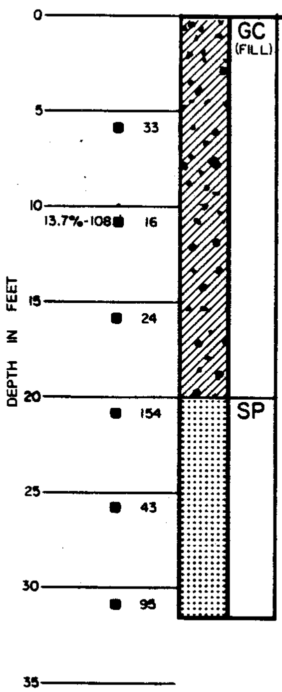
BROWN CLAYEY SILT WITH TRACE FINE SAND – MEDIUM STIFF
WATER LEVEL AT 5.5 FEET ON 8–31–84

GRADING SANDY

BORING COMPLETED AT 16.5 FEET ON 8–2–84
1.5 INCH DIAMETER SLOTTED PVC PIPE INSTALLED TO 10.0 FEET

BORING 9

ELEVATION 4809'*



DARK BROWN CLAYEY FINE AND COARSE GRAVEL WITH SOME FINE TO COARSE SAND – MEDIUM DENSE (FILL)

GRADING LOOSE

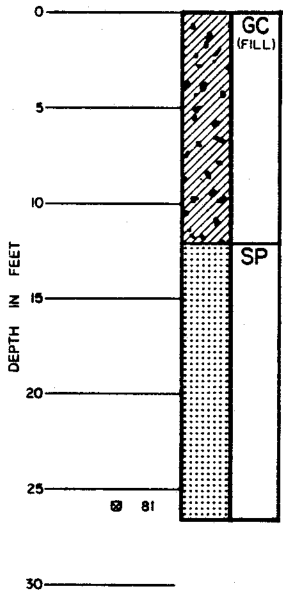
BROWN FINE TO COARSE GRAVELLY SAND WITH TRACE SILT – VERY DENSE

GRADING MEDIUM DENSE

BORING COMPLETED AT 31.5 FEET ON 31.5 FEET
1.5 INCH DIAMETER SLOTTED PVC PIPE INSTALLED TO 31.0 FEET
GROUND WATER WAS NOT ENCOUNTERED

BORING 10

ELEVATION 4809'*



DARK BROWN CLAYEY FINE AND COARSE GRAVEL WITH SOME FINE TO COARSE SAND – MEDIUM DENSE

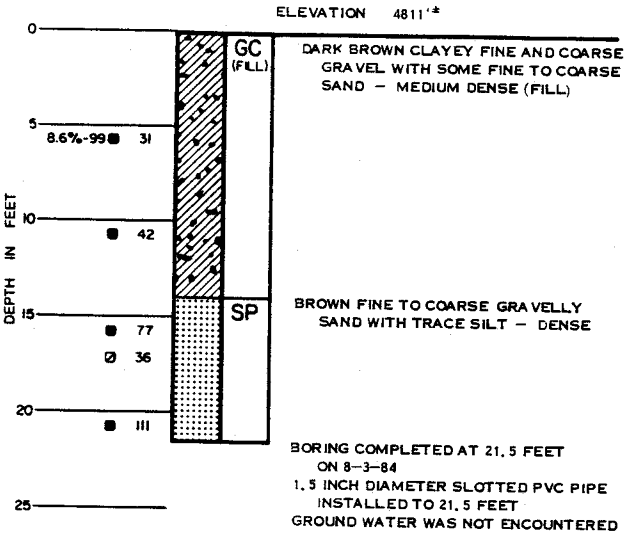
BROWN FINE TO COARSE GRAVELLY SAND WITH TRACE SILT – DENSE

BORING COMPLETED AT 26.0 FEET ON 8–2–84
1.5 INCH DIAMETER SLOTTED PVC PIPE INSTALLED TO 26.0 FEET
GROUND WATER WAS NOT ENCOUNTERED

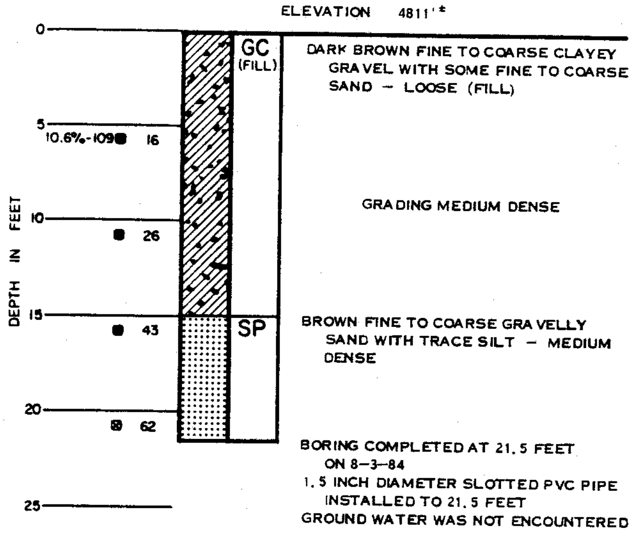
LOG OF BORINGS

Dames & Moore

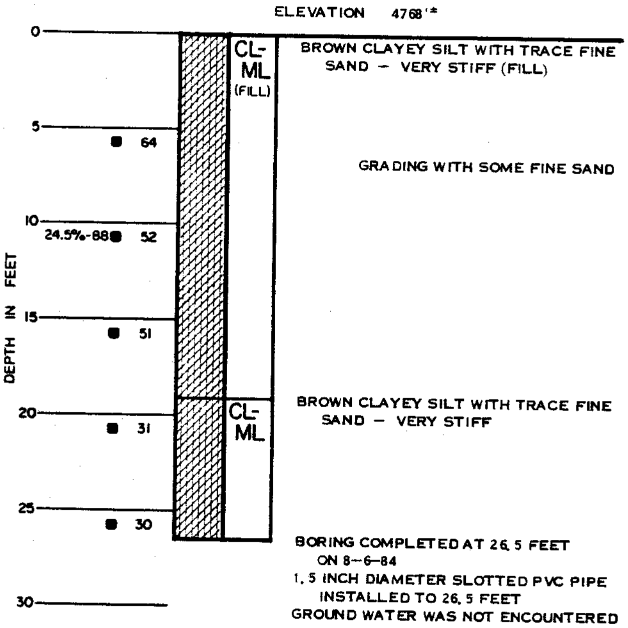
BORING 11



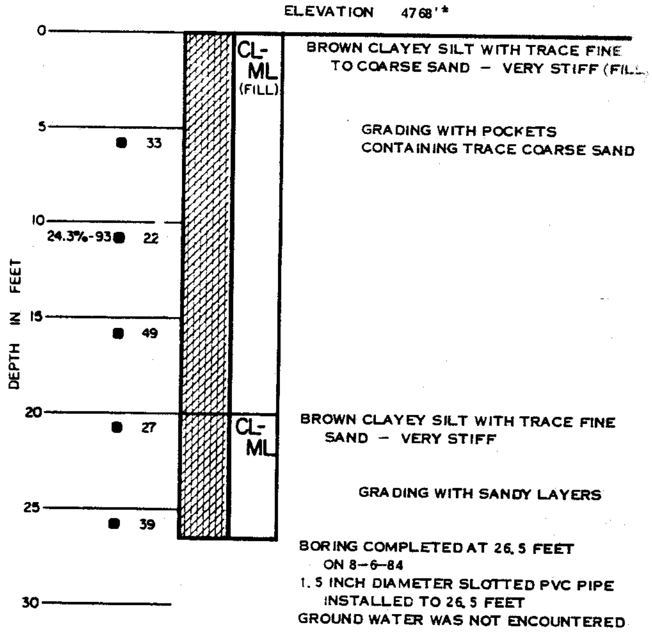
BORING 12



BORING 13



BORING 14

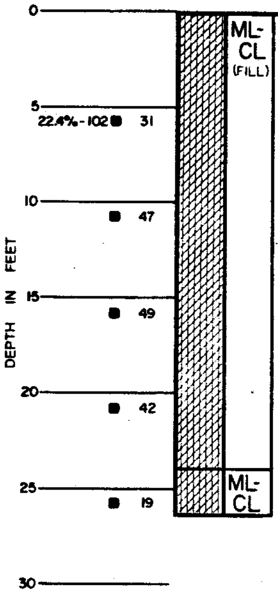


LOG OF BORINGS

Dames & Moore

BORING 15

ELEVATION 4768'±



GRAY CLAYEY SILT WITH TRACE FINE SAND – VERY STIFF (FILL)

GRADING SANDY

BROWN CLAYEY SILT WITH SOME FINE SAND AND FINE GRAVEL – STIFF

BORING COMPLETED AT 26.5 FEET ON 8–6–84

1.5 INCH DIAMETER SLOTTED PVC PIPE INSTALLED TO 26.5 FEET

GROUND WATER WAS NOT ENCOUNTERED

LOG OF BORINGS

Dames & Moore

FILE 01375-256

MAJOR DIVISIONS			GRAPH SYMBOL	LETTER SYMBOL	TYPICAL DESCRIPTIONS
COARSE GRAINED SOILS	GRAVEL AND GRAVELLY SOILS	CLEAN GRAVELS (LITTLE OR NO FINES)		GW	WELL-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
				GP	POORLY-GRADED GRAVELS, GRAVEL-SAND MIXTURES, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION <u>RETAINED</u> ON NO. 4 SIEVE	GRAVELS WITH FINES (APPRECIABLE AMOUNT OF FINES)		GM	SILTY GRAVELS, GRAVEL-SAND-SILT MIXTURES
				GC	CLAYEY GRAVELS, GRAVEL-SAND-CLAY MIXTURES
	SAND AND SANDY SOILS	CLEAN SAND (LITTLE OR NO FINES)		SW	WELL-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
MORE THAN 50% OF MATERIAL IS <u>LARGER</u> THAN NO. 200 SIEVE SIZE				SP	POORLY-GRADED SANDS, GRAVELLY SANDS, LITTLE OR NO FINES
	MORE THAN 50% OF COARSE FRACTION <u>PASSING</u> NO. 4 SIEVE	SANDS WITH FINES (APPRECIABLE AMOUNT OF FINES)		SM	SILTY SANDS, SAND-SILT MIXTURES
				SC	CLAYEY SANDS, SAND-CLAY MIXTURES
FINE GRAINED SOILS	SILTS AND CLAYS	LIQUID LIMIT <u>LESS</u> THAN 50		ML	INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS OR CLAYEY SILTS WITH SLIGHT PLASTICITY
				CL	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS, LEAN CLAYS
				OL	ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY
MORE THAN 50% OF MATERIAL IS <u>SMALLER</u> THAN NO. 200 SIEVE SIZE	SILTS AND CLAYS	LIQUID LIMIT <u>GREATER</u> THAN 50		MH	INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SAND OR SILTY SOILS
				CH	INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS
				OH	ORGANIC CLAYS OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILTS
HIGHLY ORGANIC SOILS				PT	PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS

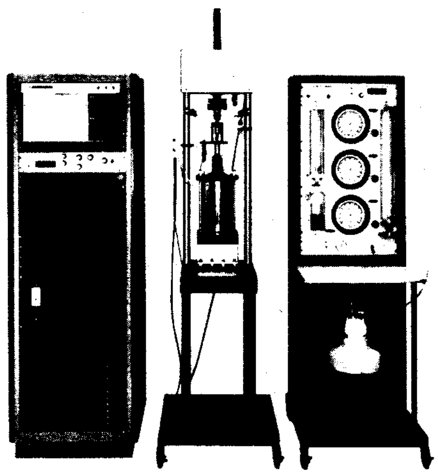
NOTE: DUAL SYMBOLS ARE USED TO INDICATE BORDERLINE SOIL CLASSIFICATIONS.

SOIL CLASSIFICATION CHART

UNIFIED SOIL CLASSIFICATION SYSTEM

DAMES & MOORE

THE SHEARING STRENGTHS OF SOILS ARE DETERMINED FROM THE RESULTS OF UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS. IN TRIAXIAL COMPRESSION TESTS THE TEST METHOD AND THE MAGNITUDE OF THE CONFINING PRESSURE ARE CHOSEN TO SIMULATE ANTICIPATED FIELD CONDITIONS.



TRIAXIAL COMPRESSION TEST UNIT

UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS ARE PERFORMED ON UNDISTURBED OR REMOLDED SAMPLES OF SOIL APPROXIMATELY SIX INCHES IN LENGTH AND TWO AND ONE-HALF INCHES IN DIAMETER. THE TESTS ARE RUN EITHER STRAIN-CONTROLLED OR STRESS-CONTROLLED. IN A STRAIN-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO A CONSTANT RATE OF DEFLECTION AND THE RESULTING STRESSES ARE RECORDED. IN A STRESS-CONTROLLED TEST THE SAMPLE IS SUBJECTED TO EQUAL INCREMENTS OF LOAD WITH EACH INCREMENT BEING MAINTAINED UNTIL AN EQUILIBRIUM CONDITION WITH RESPECT TO STRAIN IS ACHIEVED.

YIELD, PEAK, OR ULTIMATE STRESSES ARE DETERMINED FROM THE STRESS-STRAIN PLOT FOR EACH SAMPLE AND THE PRINCIPAL STRESSES ARE EVALUATED. THE PRINCIPAL STRESSES ARE PLOTTED ON A MOHR'S CIRCLE DIAGRAM TO DETERMINE THE SHEARING STRENGTH OF THE SOIL TYPE BEING TESTED.

UNCONFINED COMPRESSION TESTS CAN BE PERFORMED ONLY ON SAMPLES WITH SUFFICIENT COHESION SO THAT THE SOIL WILL STAND AS AN UNSUPPORTED CYLINDER. THESE TESTS MAY BE RUN AT NATURAL MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SOILS.

IN A TRIAXIAL COMPRESSION TEST THE SAMPLE IS ENCASED IN A RUBBER MEMBRANE, PLACED IN A TEST CHAMBER, AND SUBJECTED TO A CONFINING PRESSURE THROUGHOUT THE DURATION OF THE TEST. NORMALLY, THIS CONFINING PRESSURE IS MAINTAINED AT A CONSTANT LEVEL, ALTHOUGH FOR SPECIAL TESTS IT MAY BE VARIED IN RELATION TO THE MEASURED STRESSES. TRIAXIAL COMPRESSION TESTS MAY BE RUN ON SOILS AT FIELD MOISTURE CONTENT OR ON ARTIFICIALLY SATURATED SAMPLES. THE TESTS ARE PERFORMED IN ONE OF THE FOLLOWING WAYS:

<u>UNCONSOLIDATED-UNDRAINED</u>: THE CONFINING PRESSURE IS IMPOSED ON THE SAMPLE AT THE START OF THE TEST. NO DRAINAGE IS PERMITTED AND THE STRESSES WHICH ARE MEASURED REPRESENT THE SUM OF THE INTERGRANULAR STRESSES AND PORE WATER PRESSURES.

<u>CONSOLIDATED-UNDRAINED</u>: THE SAMPLE IS ALLOWED TO CONSOLIDATE FULLY UNDER THE APPLIED CONFINING PRESSURE PRIOR TO THE START OF THE TEST. THE VOLUME CHANGE IS DETERMINED BY MEASURING THE WATER AND/OR AIR EXPELLED DURING CONSOLIDATION. NO DRAINAGE IS PERMITTED DURING THE TEST AND THE STRESSES WHICH ARE MEASURED ARE THE SAME AS FOR THE UNCONSOLIDATED-UNDRAINED TEST.

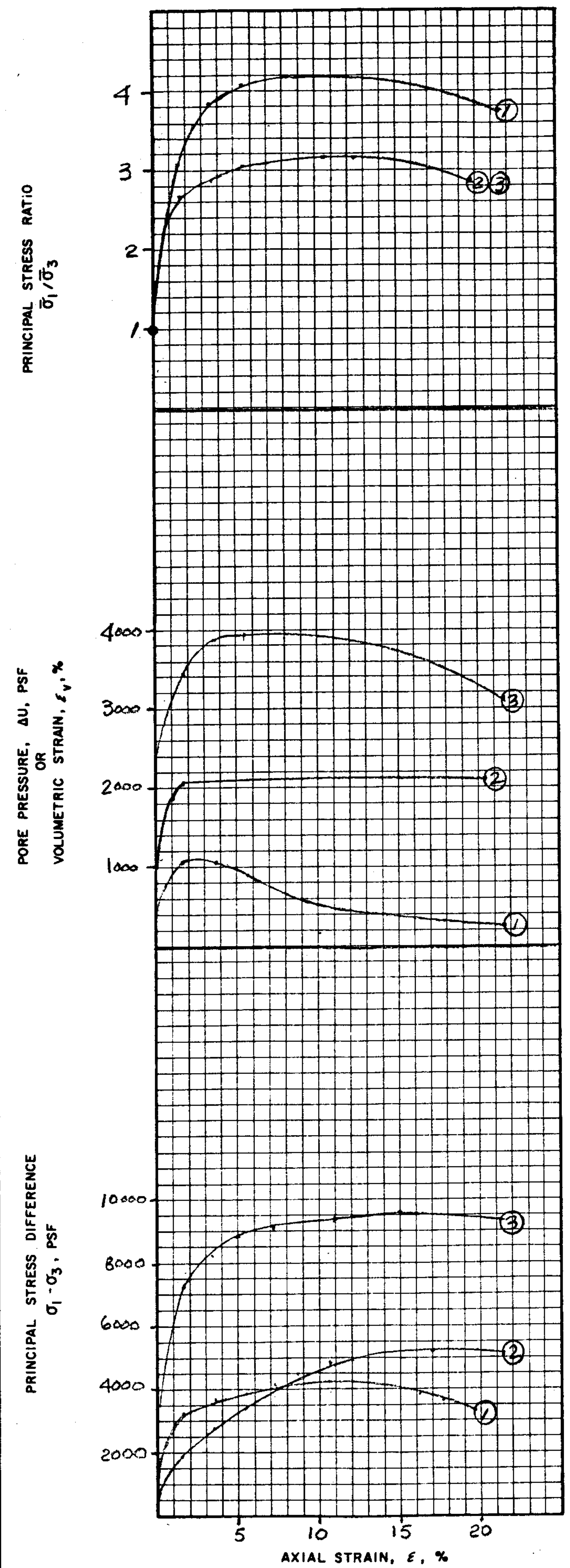
<u>DRAINED</u>: THE INTERGRANULAR STRESSES IN A SAMPLE MAY BE MEASURED BY PERFORMING A DRAINED, OR SLOW, TEST. IN THIS TEST THE SAMPLE IS FULLY SATURATED AND CONSOLIDATED PRIOR TO THE START OF THE TEST. DURING THE TEST, DRAINAGE IS PERMITTED AND THE TEST IS PERFORMED AT A SLOW ENOUGH RATE TO PREVENT THE BUILDUP OF PORE WATER PRESSURES. THE RESULTING STRESSES WHICH ARE MEASURED REPRESENT ONLY THE INTERGRANULAR STRESSES. THESE TESTS ARE USUALLY PERFORMED ON SAMPLES OF GENERALLY NON-COHESIVE SOILS, ALTHOUGH THE TEST PROCEDURE IS APPLICABLE TO COHESIVE SOILS IF A SUFFICIENTLY SLOW TEST RATE IS USED.

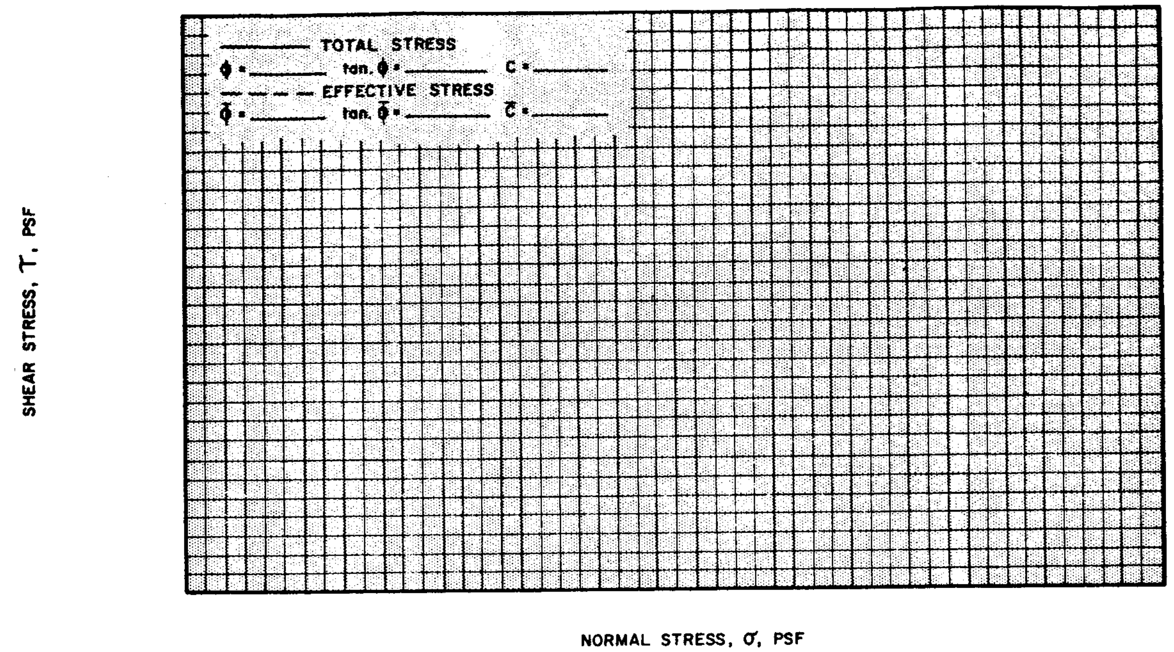
AN ALTERNATE MEANS OF OBTAINING THE DATA RESULTING FROM THE DRAINED TEST IS TO PERFORM AN UNDRAINED TEST IN WHICH SPECIAL EQUIPMENT IS USED TO MEASURE THE PORE WATER PRESSURES. THE DIFFERENCES BETWEEN THE TOTAL STRESSES AND THE PORE WATER PRESSURES MEASURED ARE THE INTERGRANULAR STRESSES.

METHODS OF PERFORMING UNCONFINED COMPRESSION AND TRIAXIAL COMPRESSION TESTS

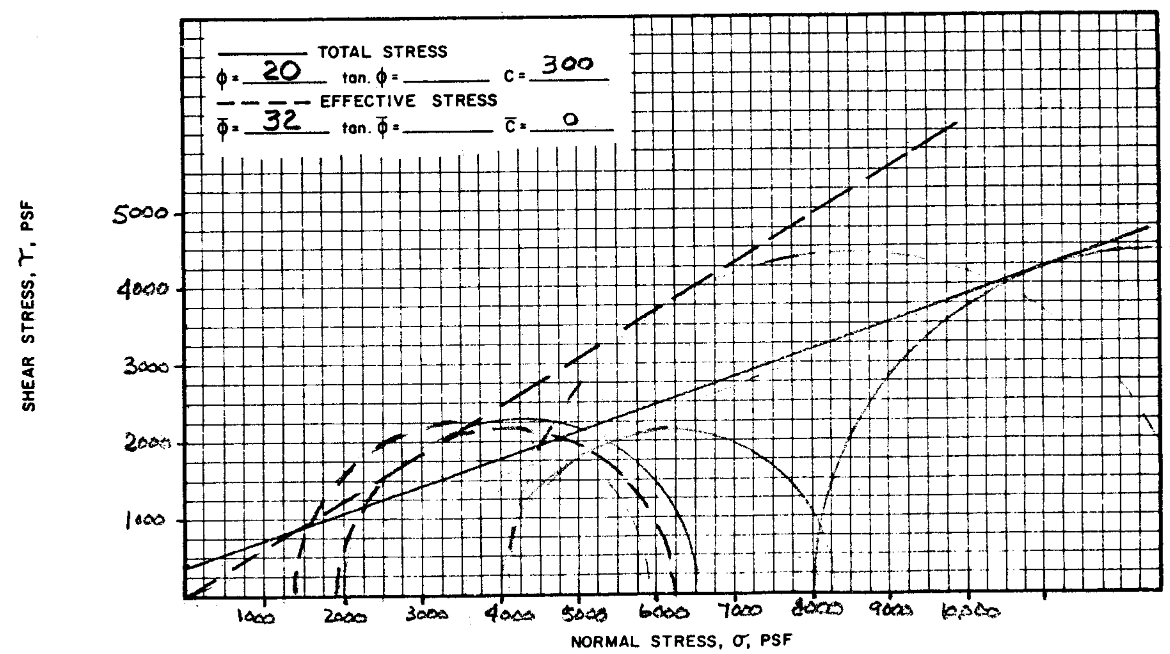
KEY		(1)	(2)	(3)	( )
BORING		1	1	1	
SAMPLE		1	2	3	
DEPTH (FEET)		5.0	10.5	20.5	
INITIAL	ω, %	31.6	47.9	22.1	
	γ_d, PCF	88	71	102	
	e_o				
	B	.73	.82	.48	
FINAL	ω, %	30.4	41.7	21.2	
	γ_d, PCF	92	79	110	
	e_f				
	B	.96	.96	.97	
BACK PRESSURE (PSI)		58	38	67	
STRAIN RATE (INCHES / MINUTE)		.002	.002	.002	

STRESS CONDITION		(1) PEAK $\sigma_1 - \sigma_3$	(1) MAX. $\bar{\sigma}_1/\bar{\sigma}_3$	(2) PEAK $\sigma_1 - \sigma_3$	(2) MAX. $\bar{\sigma}_1/\bar{\sigma}_3$	(3) PEAK $\sigma_1 - \sigma_3$	(3) MAX. $\bar{\sigma}_1/\bar{\sigma}_3$	( ) PEAK $\sigma_1 - \sigma_3$	( ) MAX. $\bar{\sigma}_1/\bar{\sigma}_3$
TOTAL STRESS	ε, %		8.9		10.7		5.5		
	TIME TO FAIL (MIN.)								
	σ_3, PSF		2000		4000		8000		
	$\sigma_1 - \sigma_3$		4493		4232		8808		
	σ_1, PSF		6493		8232		16808		
	$\frac{1}{2}(\sigma_1 - \sigma_3)$		2247		2116		4404		
	$\frac{1}{2}(\sigma_1 + \sigma_3)$		4293		6116		12404		
	u, PSF		590		2059		3931		
	A, $u/(\sigma_1 - \sigma_3)$		.13		.49		.44		
EFFECTIVE STRESS	ε, %		8.9		10.7		5.5		
	TIME TO FAIL (MIN.)								
	$\bar{\sigma}_3$, PSF		1410		1941		4069		
	$\bar{\sigma}_1 - \bar{\sigma}_3$		4493		4232		8808		
	$\bar{\sigma}_1$, PSF		5903		6173		12877		
	$\frac{1}{2}(\bar{\sigma}_1 - \bar{\sigma}_3)$		2247		2116		4404		
	$\frac{1}{2}(\bar{\sigma}_1 + \bar{\sigma}_3)$		3656		4057		8473		
	u, PSF		590		2059		3931		
	A, $u/(\bar{\sigma}_1 - \bar{\sigma}_3)$		.13		.49		.44		
	$\bar{\sigma}_1/\bar{\sigma}_3$		4.2		3.2		3.2		
REMARKS									





MOHR ENVELOPE – PEAK STRESS



MOHR ENVELOPE – MAXIMUM EFFECTIVE STRESS RATIO

TRIAXIAL COMPRESSION TEST REPORT

TYPE OF TEST CONSOLIDATED - UNDRAINED

TYPE MATERIAL SILTY CLAY

SAMPLE DESCRIPTION

CLASSIFICATION CL/ML

LIQUID LIMIT ____ PLASTIC LIMIT ____ SPECIFIC GRAVITY, G_s ____

PROJECT EVAPORATION PONDS

LOCATION BINGHAM CANYON

JOB NO. 1375-056 PREPARED BY JFZ, 9/4/84

CHECKED BY ____, / /

Storm Water Containment Ponds